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Canadian Aeronautical Journal

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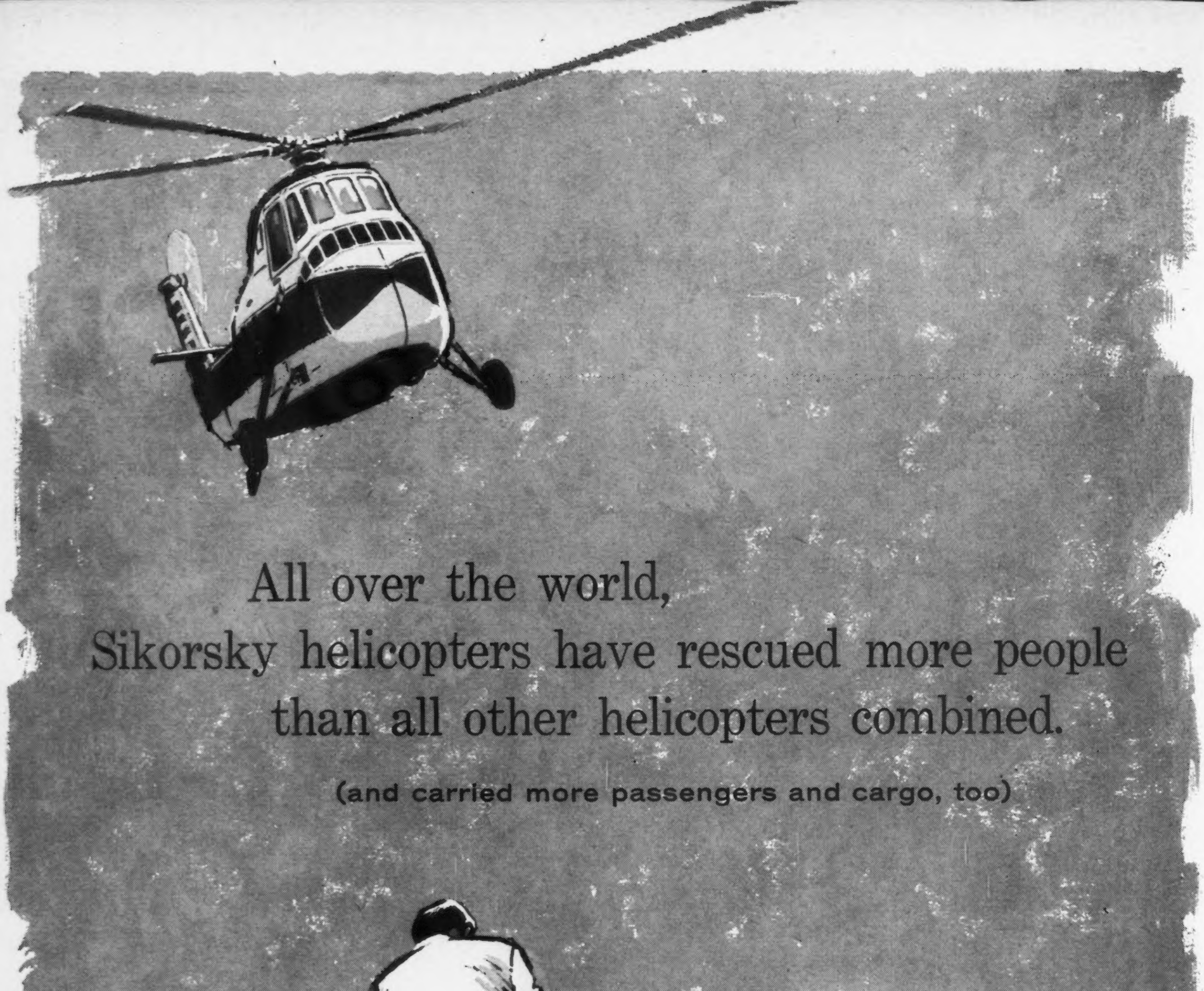
All over the world,
Sikorsky helicopters have rescued more people
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(and carried more passengers and cargo, too)

CANADIAN AERONAUTICAL INSTITUTE

CANADIAN AERONAUTICAL JOURNAL

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CANADAIR FORTY-FOUR

The model shown is the conventional side-loading version of the Canadair Forty-Four Transport, powered by four Rolls-Royce Tyne 12 turboprop engines. The largest aircraft ever built in Canada, the Forty-Four is designed specifically to meet the immediate requirements of the air-cargo industry. A swing-tail, rear-loading version is also on order.

EDITORIAL

THE MAZE

This month we have a story to tell. In a sense it is a story against ourselves; for it condemns us of poor staff work, which failed to overcome a familiar problem of our age. But it is the problem itself to which we would draw attention.

The participants in the recent Anglo-American Conference were the Institute of the Aeronautical Sciences, the Royal Aeronautical Society and, in a rather small way, the Canadian Aeronautical Institute. The programme consisted of three days of technical sessions in New York, two days of visits to plants and establishments in Toronto and, in between, four or five days of visits to plants and establishments in the USA. This American tour of visits was intentionally confined to the RAeS delegation from Great Britain – for a number of very good reasons – but the IAS agreed that one or two Canadians might be included if proper security clearances could be obtained.

A certain member of the CAI – let us call him Mr. Smith – was very anxious to visit some of the plants on the American tour. Mr. Smith is a senior executive of a Canadian subsidiary of a well-known British firm, where he was employed before coming to Canada three or four years ago. He is a member of the RAeS, as well as of the CAI, and as such he had received the RAeS notice of the Conference, which made reference to this tour of American facilities.

Mr. Smith asked the Secretary of the CAI about these visits and was told that they were intended for the British visitors only, but it was suggested that, if he was particularly anxious to be included in the party, he might consult the IAS. This he did and was advised that the matter turned on his obtaining clearance through the RAeS channels. So he wrote to the RAeS, pointing out that the British authorities, and in particular his parent firm, knew all about him. The RAeS put forward his case to the Ministry of Supply, which was handling the clearances of the RAeS delegates through the British Joint Services Mission in Washington. The Ministry replied that Mr. Smith, as a resident of Canada, would have to get clearance through the Department of Defence Production in Ottawa. Mr. Smith was now nicely in orbit.

He consulted the Secretary of the CAI again and they decided that he had better do as he was told and approach the DDP. In the meantime the Secretary phoned the IAS and discovered the name of the officer in the BJSM who was dealing with the Pentagon about the British clearances; it was important that Mr. Smith's name should eventually appear on the same list. In due course the DDP checked with the CAI, to obtain the precise addresses of the plants and establishments to be visited, and the Secretary took the opportunity to ask them to establish liaison with the officer concerned in the BJSM. But this could not be done; the DDP must deal with the Pentagon through its own office in Washington. The Secretary then asked where the requests for clearance would be addressed and was told that, since contractors to the US Army, US Navy and USAF were involved, the requests would be sent to three specific Rooms in the Pentagon – Rooms A, B and C. Armed with this advice the Secretary wrote to the officer in the BJSM and asked him to do his best to trace these clearances in Rooms A, B and C and see that Mr. Smith's name was added to the list of RAeS delegates.

And there the story ends. Mr. Smith's name never got on the list.

A similar case occurred when the Anglo-American Conference was held in England two years ago. On that occasion a Canadian, a member of all three societies, who had served nearly thirteen years with the Air Ministry, MAP and MoS before coming to Canada, was unable to get clearance to visit British defence contractors. And no doubt similar difficulties would occur in Canada, given the opportunity of an Anglo-American Conference held in this country. The whole business of international clearances is so complicated that it presents a real barrier to the exchange of technical information. Perhaps there is nothing that can be done about it but, if the IAS and RAeS can establish interconnecting channels through this labyrinth of red tape when their own nationals are concerned, it should be possible for the system to be extended; the three societies, dedicated to the exchange of information, have a common duty to their members in finding a way out.

RECENT TRENDS IN AERONAUTICS AND SPACE RESEARCH IN THE UNITED STATES†

by Dr. H. L. Dryden*

National Aeronautics and Space Administration

"It is not necessary to look too far into the future; we see enough already to be certain that it will be magnificent."

—Wilbur Wright

INTRODUCTION

It is a great pleasure for me to meet with you on this anniversary of the first flight of an airplane in Canada, which was also the first by a British subject within the British Empire. I join with you in paying tribute to J. A. D. McCurdy, Canadian pioneer of flight. His presence reminds some of us that we belong to the generation which saw man leave the surface of the earth in controlled flight through the air. My old friend, J. H. Parkin, and I have witnessed and played a small part in the amazing developments of a half century that have brought us conquest of the air and the beginnings of the exploration of interplanetary space. Our collaboration and friendship have been typical of the neighborly co-operation of the citizens, institutions and governments of Canada and the United States. On this historic occasion I bring you greetings from my colleagues in the Institute of the Aeronautical Sciences and in the National Aeronautics and Space Administration, a new United States governmental agency for research and development in aeronautics, space science, space technology and space flight.

My assignment on this occasion is that of looking toward the future, to look at the sweep of events from the flight of the Silver Dart through the past to the present and toward the future. Rather than compete with the writers of science fiction or with prophets who claim to discern clearly the events of several decades in the future, I will concentrate on the trends of the recent past and their extrapolation into the near future.

In July of 1953, I was maneuvered into publishing in Aero Digest a prophecy of developments in aeronautics for the next fifty years. The prophets of the past were classed as pessimists, fence-straddlers and optimists, and the future was viewed through the eyes of each group. I would like to quote two paragraphs.

"If there is any twentieth-century aspiration which corresponds to that of the nineteenth century for conquest of the air, it is perhaps that of the conquest of space with the early goal, travel to the moon. Like the concepts of flight during the nineteenth century, these concepts of space travel are the results of attempts of imaginative men to apply the technology of their day to the problems of interplanetary travel. It may well be that success will await a still broader basis of experience in science and technology, experiment and more experiment, and unanticipated scientific developments. Let us again listen to Dr. Optimist as he speaks in nearly the same terms as one of the prophets of fifty years ago.

"There are few today who do not look forward with feelings of confidence that space flight will some day be accomplished. All that we require is to make rocket motors somewhat larger than those already in existence. To accomplish this all that is required is the pooling of skills already available and a good deal of money. Taking into consideration the speed at which guided missiles travel, that at which models have been propelled, the experimental data available from hypersonic experiments in wind tunnels and ranges, and the theoretical calculations which have been made, we may reasonably suppose that a satellite vehicle is entirely practicable now and that travel to the moon is attainable in the next fifty years."

Five and one-half years have passed since these words were written. The first satellite was launched a little over a year ago. In recent testimony before the United States Congress, I stated that we could have a lunar expedition within ten to fifteen years if the necessary financial and other resources were allocated to this project. Another scientist testified that he thought it could be done within seven and a half years. Such has been the effect of the first step into space on our thinking.

Rather than engage in a contest of prophecy, let us turn our attention to recent trends in aeronautical and space research in the United States, as illustrated by activities in which the former National Advisory Committee for Aeronautics and its successor agency, the National Aeronautics and Space Administration, is now, or has been, involved. Trends in other aeronautical research agencies and in industry groups in the United States are similar.

†Paper read at the Special Anniversary Meeting of the C.A.I. in Montreal on the 23rd February, 1959.
*Deputy Administrator.

We will find that progress has been evolutionary, except for a few step-like jumps, as radically improved propulsion systems became practical. We will find that we now have before us another step-like jump connected with the development of large rocket engines. We will find new factors. No longer can a McCurdy or a Lindbergh pioneer the next advance. The dimensions of space exploration are too large. Pioneering nations replace pioneering individuals. Space exploration is the prerogative of the largest and most powerful nations of the world; perhaps it will require ultimately the support and cooperation of all mankind.

TURBOJET ENGINES AND THE SUPERSONIC AGE

Powered flight was made possible by the development of reciprocating internal combustion engines. This type of engine grew in performance and reliability through the first half-century of flight, enabling steady advances in the performance of civil and military aircraft. During the last war, American manufacturers turned out 257,000 such engines in a single year. The air war was fought and won with aircraft equipped with piston engines and propellers.

On August 27, 1939, unknown to the rest of the world, the Germans flew a Heinkel 178 airplane powered by a radically different type of powerplant, the turbojet. There began a technical revolution which advanced aircraft performance at an unprecedented rate to that of our present-day jet fighters, jet bombers and civil jet aircraft.

These performance gains were not wholly due to the development of the turbojet engine. Simultaneous developments were required and made in other branches of technology. Jet engines had limited utility in the aircraft in which they were first flown. We had to learn to postpone compressibility effects, to reduce drag at transonic speeds by use of sweepback and thinner wing sections. A new concept of design, in which the entire configuration of wings and fuselage was shaped to give a smooth distribution of cross-sectional area along the axis of the fuselage, produced tactical military aircraft with useful supersonic performance. These aerodynamic improvements were made practical by the development of new materials and structural designs and the solution of aeroelastic and flutter problems. Thus the phenomenal increase in rate of advance of aircraft performance was made possible by the new type of powerplant accompanied by harmonious and coordinated rapid progress in the development of the new powerplants, airframe configurations, materials and structures.

Initiated by the inventive development of the turbojet engine, the technical revolution early made its presence felt in a drastic reorientation of aeronautical research programs. In the United States, the National Advisory Committee for Aeronautics on January 18, 1941, began construction of a major new laboratory at Cleveland to be devoted solely to research on flight propulsion. It had been planned in terms of piston engines. In May of the same year the British made the first flight with Whittle's jet engine in the Gloster airplane, a development quite independent of the earlier German jet engine. Following the entry of the United States into the war, intensive research was initiated on the new type of powerplant and on its applications in aircraft design. The NACA Flight Propulsion Laboratory was completely re-equipped for this work and its programs of research drastically changed.

Studies of the possibility of supersonic flight were begun by the NACA in 1942 but no suitable powerplant was then available. It was proposed to carry out supersonic research by flight tests, because the wind tunnels then available became useless at speeds near that of sound. In 1944 a cooperative program was initiated by the Army, Navy and the NACA. A liquid fuel rocket engine was selected as the powerplant and air-launching from a mother aircraft provided higher performance than could be obtained by an aircraft designed for takeoff from the ground. Flights of research airplanes contributed aerodynamic and structural data and operating experience to the development of tactical supersonic military aircraft powered with improved turbojet engines.

ROCKETS, MISSILES AND HYPERSONIC FLIGHT

I have noted that the "break-through" to turbojet-powered supersonic aircraft depended not only on a new device but on timely and appropriate developments in aerodynamics, materials and structures. In the "break-through" to the rocket-powered hypersonic Intercontinental Ballistic Missile we find no single new invention, but the simultaneous maturity of developments in many fields. The principles of rocket propulsion are inherent in Newton's laws of motion. Small rockets were developed centuries ago. In the United States, Dr. Robert H. Goddard began experimental work in 1914. In 1929 he fired a small rocket using gasoline and liquid oxygen as propellants. His work was little appreciated at the time. Only when German scientists and engineers unveiled the 12-ton V-2 rocket did the rest of the world re-examine the potentialities of rocket propulsion.

The development of the ICBM has been made possible by the rapid development of the V-2 type rocket coupled with new developments in lightweight structures, in lightweight but powerful nuclear warheads, in the art of guidance, and in means for dealing with the problem of aerodynamic heating on re-entry. The high priority given to the development of this weapon system has attracted research effort to the relevant fields of science and technology.

Thus in recent years NASA Research Centers, formerly laboratories of NACA, directed increased research effort to the problems of aerodynamics at hypersonic speeds. The objectives included more fundamental understanding of the airflow at hypersonic speeds characteristic of re-entry of ballistic missile nose cones to the atmosphere, including the high temperatures developed, the physical and chemical changes in the air near the nose cone and their effect on the flow. Theoretical and experimental studies of heat transfer, forces applied and stability were made. One of the techniques developed at the NASA Wallops Island Research Station is illustrated in Figure 1. The figure shows a five-stage missile research rocket which can be fired to an altitude of about 100,000 ft by means of the first two stages. The last three stages are fired on a descending path to simulate re-entry conditions of ballistic missiles. The rocket shown attains a re-entry speed of over 3 miles per second (Mach 16).

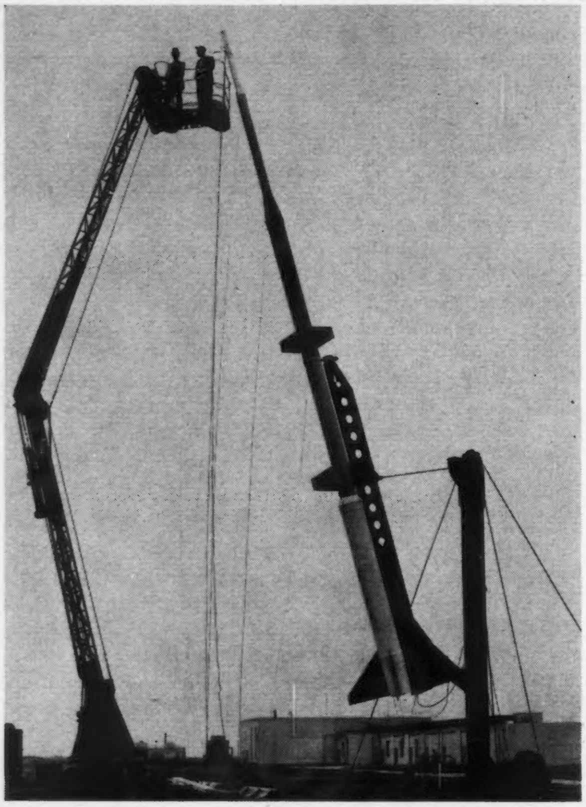

Figure 1

Five-stage missile research rocket at NASA Wallops Island Station used to study re-entry at speeds of 3 miles per second

Temperatures, heat transfer and other data are obtained by radio telemetering. Many research groups in the United States, Great Britain and Canada now use this technique.

In 1952, H. J. Allen of the NASA Ames Research Center contributed the concept of the high-drag blunt nose cone to minimize aerodynamic heating. All current ICBM and IRBM nose cones employ this concept. Extensive studies of the heating, drag and stability have since been made by NASA and by industry groups in the United States.

New laboratory techniques were developed for tests of high temperature materials under conditions approaching those encountered during re-entry of ballistic missile nose cones. Figure 2 shows a ceramic-heated jet at the NASA Langley Research Center capable of testing specimens of materials in a 4000°F airstream from 4 to 12 inches in diameter. Figure 3 shows a specimen under test in this jet. Temperatures of 12,000°F are attained in the electric-arc powered air jet shown in Figure 4. These tools indicate the trends of research within the last few years in aerodynamics, heat transfer and materials with special reference to ballistic missile applications. The basic data obtained are more widely applicable to the corresponding problems of any hypersonic vehicle.

NASA research on rocket engines in recent years has been both theoretical and experimental. Theoretical studies have been made of rocket cycle thermodynamics, flight dynamics, calculation by use of digital computers of the combustion gas composition and temperature under a variety of conditions, and of the vehicle performance that may be realized. Experimental work has included the fundamentals of propellant mixing and atomization, reactivity of fuel-oxidant combinations, ignition and starting at high altitude and low temperature, combustion instability and heat transfer.

HYPERSONIC AIRCRAFT

NASA Research Centers have for the past decade advocated and carried out, in cooperation with the Air Force and Navy, research on the problems of future aircraft through the use of specially designed research airplanes. The original series, X-1, X-2, X-3, D-558-1 and D-558-2, are well known. The Bell X-2 exceeded a speed of three times the speed of sound and reached an altitude in excess of twenty-five miles.

Two years before the X-2 made these records, NASA made a proposal for a follow-on airplane to explore the adjoining higher speed range and to study some of the problems of manned flight into nearby space. This proposal resulted in another cooperative project for the X-15 research airplane which will soon begin its flight program. This airplane is designed to reach altitudes where aerodynamic forces are negligible. Small rockets are provided for space controls. Re-entry into the atmo-

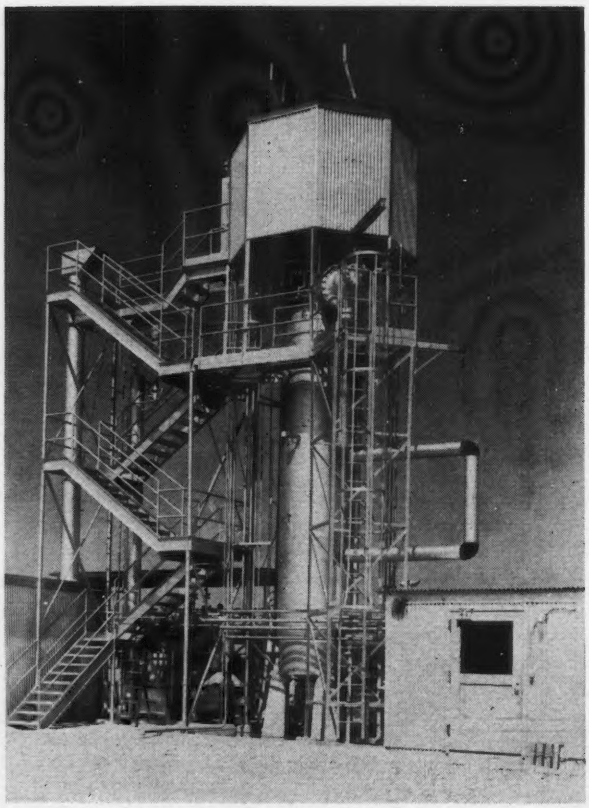

Figure 2

Ceramic-heated jet capable of testing materials specimens in a 4000°F airstream from 4 to 12 inches in diameter

sphere may be studied. The materials and construction of the X-15 have been designed to withstand surface temperatures during re-entry up to 1200°F. Possible flight plans permit several minutes of weightlessness. Thus the pilot may gain experience with this condition which may be encountered in space flight.

The X-15 program has included associated studies by means of laboratory simulators of man's ability to control the vehicle both within and beyond the atmosphere. The requirements for stabilization and control of the X-15 were formulated in the light of these studies.

More recently NASA Research Centers have been making an intensive study of the feasibility of a research hypersonic glider with an airframe capable of flight at all speeds up to satellite velocity. Such a glider could

Figure 3
Model during test in 4000°F airstream

be boosted to high altitude and speed by the use of rockets, and then glide for long distances within the upper atmosphere. Such a vehicle would be capable of exploring the problem of manned space flight and re-entry at extreme speeds. One of the many configurations under study in wind tunnels is shown in Figure 5. The figure shows a large dynamically scaled model in free flight in a large slow speed wind tunnel to study approach and landing behaviour.

RESEARCH ON THE PROBLEMS OF SPACE FLIGHT

The interest of NACA in the research problems of space flight began in a formal sense with a presentation by the late Robert J. Woods, of Bell Aircraft Corporation, to his fellow members of the NACA Committee on Aerodynamics at its regular meeting on January 30,

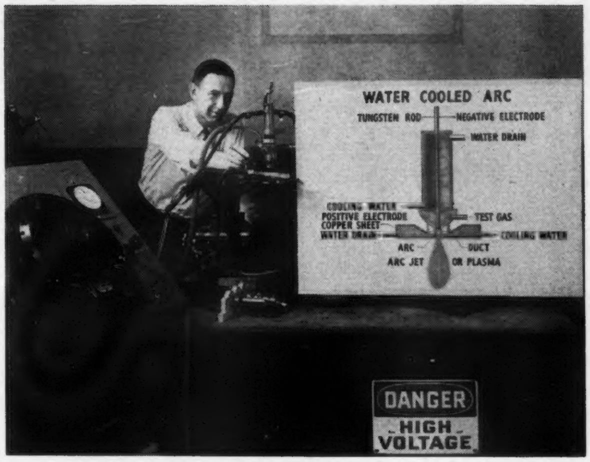

Figure 4
Electric-arc powered air jet

1952. Mr. Woods urged basic research on the mechanics and problems of space flight and the establishment of a concept of a suitable manned test vehicle and the building of such a vehicle as soon as possible. The latter recommendation led to the X-15 research airplane program already mentioned.

The first part of the recommendation led to the design and construction of special research facilities and a fairly extensive reorientation of the research programs of the NACA laboratories in aerodynamics, propulsion and structures. At first this effort was directed mainly toward and integrated by the X-15 project. More recently the studies have been oriented to provide basic information needed in the design of recoverable manned satellites and true spacecraft.

Many new wind tunnels with unique features have provided the means for closer simulation of the flight environment. These include low-density wind tunnels, special hot wind tunnels for heat transfer studies, and hypersonic wind tunnels using air and helium. Small tunnels using air provide speeds up to Mach 10. A large new wind tunnel will provide a hypersonic air stream

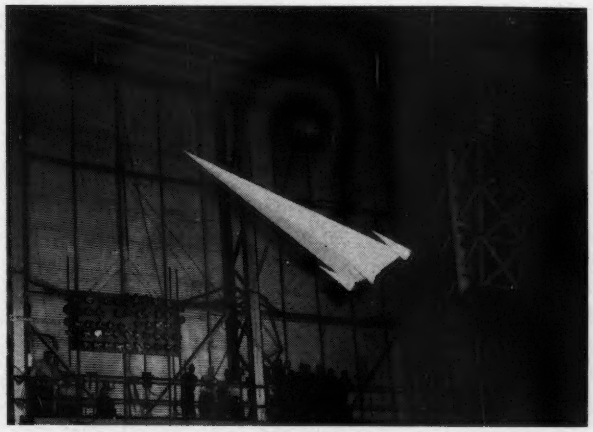

Figure 5
Dynamically scaled model of hypersonic glider in free flight in a large low speed wind tunnel

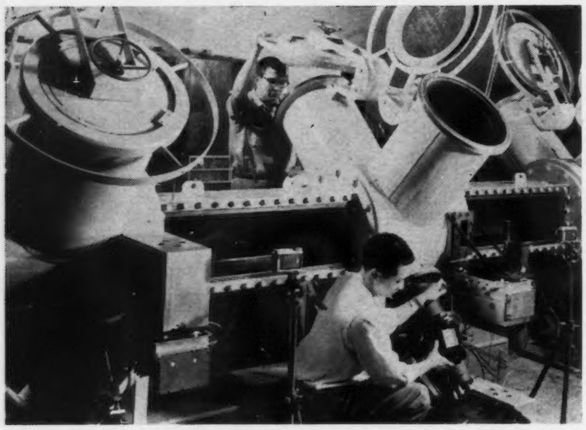

Figure 6
Light gas gun test chamber of hypersonic range

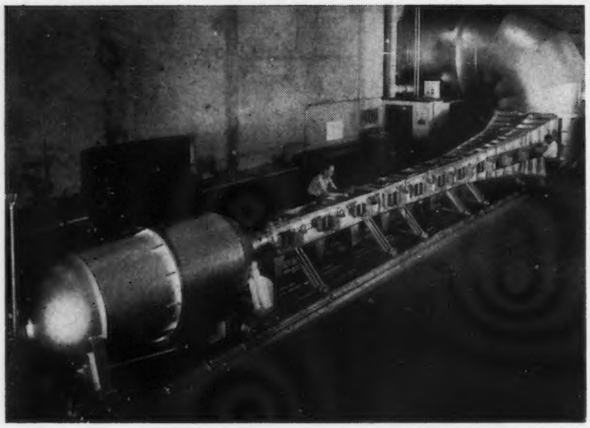

Figure 8
Atmosphere entry simulator

with stagnation temperature in the 2500°F to 3000°F range. Helium has been used in small wind tunnels to simulate Mach numbers up to 20, and larger helium wind tunnels are under construction.

One of the most valuable research tools is the hypersonic ballistic range which provides both the speed and the corresponding stagnation temperature at the full-scale values. Figure 6 shows the flight test chamber of the Ames Research Center's ballistic range with the many photographic stations for recording attitudes and shock wave patterns at various points along the flight path. The models are launched by a light gas gun which propels them down the range at speeds of 15,000 ft per second or more. In air the intense heating raises the temperature to the point where the air at the nose is luminous and, in some cases, melting or burning may occur. Figure 7 shows the luminous trace of a magnesium projectile at 12,000 ft per second. By substituting other gas mixtures for air, conditions corresponding to flight in the atmospheres of other planets can be simulated.

The Ames Atmosphere Entry Simulator (Figure 8) consists of a high velocity gun and a hypersonic nozzle which is so shaped that the flow of high pressure air accelerated through it duplicates the way in which the density of the earth's atmosphere decreases with altitude. A model launched at full re-entry velocity along the axis of the nozzle toward the small diameter high density region duplicates the decelerations, stresses, pressures and temperatures of actual re-entry.

In the propulsion field, the requirements of spacecraft propulsion have brought special research emphasis on nuclear and electric propulsion systems. The nuclear facility of NASA at Plumbrook Arsenal near Sandusky, Ohio, shown in Figure 9, provides a 60 megawatt research reactor to further research on the effects of heat and radiation on powerplant materials and components.

For propulsion in interplanetary space in extremely weak gravitational fields there is great interest in ion or plasma jets accelerated by electrical means because of the extremely low propellant consumption as compared with other powerplants. This advantage is accompanied by the disadvantage of small thrust and large powerplant weight. One of the new facilities used for the study of ion rockets is shown in Figure 10.

The structures of space vehicles are not subject to large gravitational or other forces when in free space. NASA has been interested in extremely lightweight in-

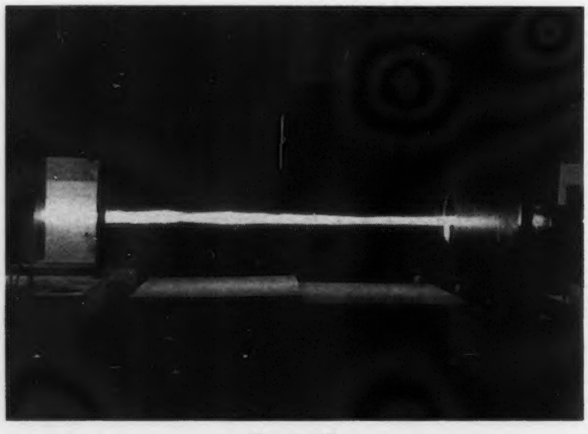

Figure 7
Magnesium projectile launched from light gas gun at 12,000 ft per second

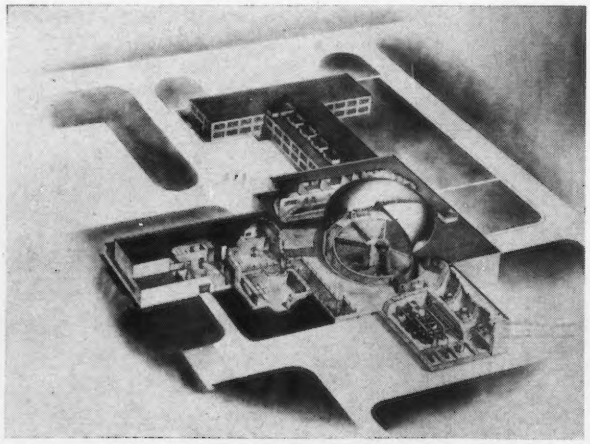

Figure 9
Sixty megawatt nuclear propulsion facility

flatable structures for special applications in space, specifically to reflectors of radio waves for communications applications. A sphere 100 ft in diameter weighing only 65 lb has been constructed (Figure 11). It can be packaged for firing into satellite orbit in a sphere only 2 ft in diameter. Figure 12 shows an inflatable corner reflector about 12 ft in diameter.

These examples indicate some of the directions in which research is moving into the problems of space flight and the types of equipment being provided. There are many more, such as space environmental chambers and simulators of many types, including the closed-loop type at the Navy's Johnsville Centrifuge with a human pilot exercising control motions feeding computers which compute the resulting motions of hypothetical vehicles and feed the accelerations to the pilot.

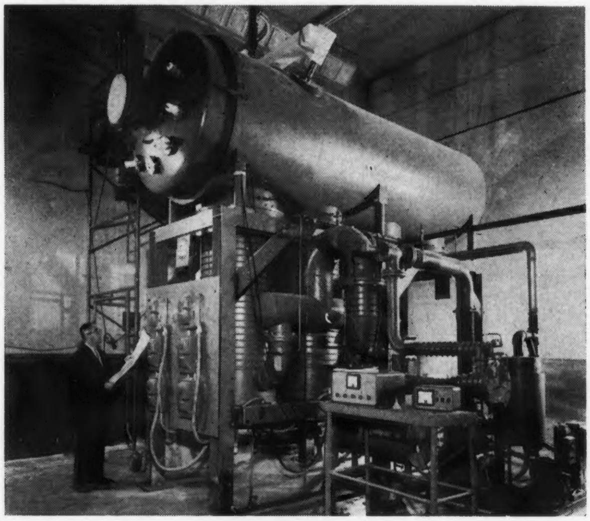

Figure 10
Ion rocket test facility

THE EXPLORATION OF SPACE

The launching of the first man-made satellite on October 4, 1957, brought a realization of the potentialities of the exploration of space and of the practicality of much more rapid progress. The NASA was created in the United States to enter upon a comprehensive program not only of research in aeronautics and space but also the development and operation of space vehicles for research purposes, and the exploration of space by unmanned and manned vehicles. A brief general survey of the United States national space program will perhaps serve to look toward the future.

Our first satellites and space probes have been assembled from components already on hand or requiring only a short time to build. The basic first stage rockets available are those developed for ballistic missiles. Only the Vanguard system was specially developed to launch satellites. The payload capability was small.

The payload of a satellite or space probe is a rough indication of the magnitude of the task that can be accomplished, whether the mission is scientific or military. It is a direct function of the rocket thrust available and of the optimization of the staging of the vehicle

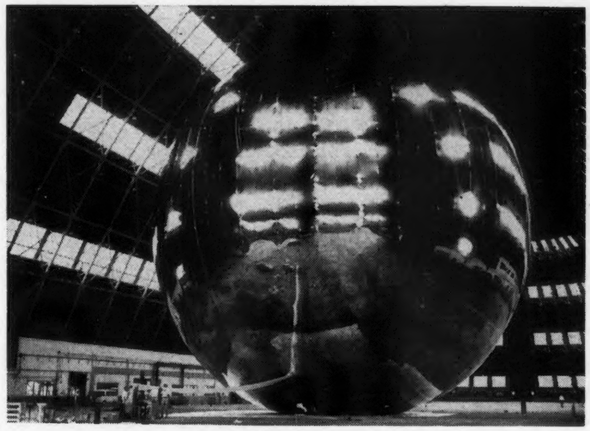

Figure 11

One hundred foot diameter inflatable sphere

system. An early task of NASA was the planning of a program of rocket and vehicle development which would provide for all the desired missions with a minimum number of new rockets and new vehicles. There are available from the ballistic missile program, Jupiter, Thor, Atlas and Titan boosters. For increased thrust, two new developments have been started in the United States — (1) a cluster of existing engines to give an early capability of about 1¼ million pounds thrust, and (2) a new single-chamber rocket of 1 to 1½ million pounds thrust, which can be clustered to give 6 million pounds thrust.

In addition to these first stage boosters, suitable upper stage rockets are under development, including some using high energy fuels. It appears that the number of sizes required will be small, perhaps no more than four. Nuclear rockets are being developed by the Atomic Energy Commission and the NASA as is the general application of nuclear energy for various purposes in the exploration of space.

This major segment of the program, which we may characterize as advance in space technology, also in-

Figure 12
Twelve foot lightweight inflatable reflector

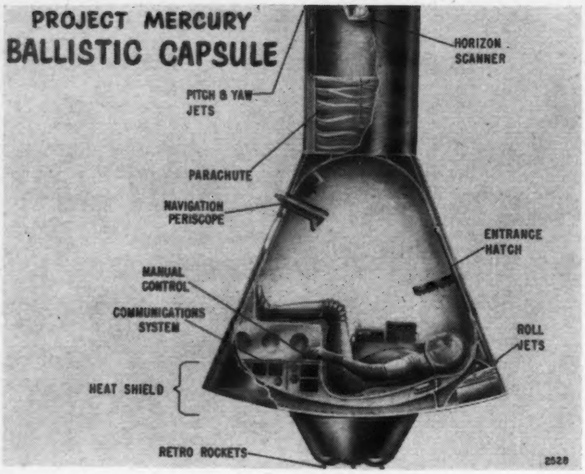

Figure 13
Manned satellite capsule

cludes the improvement of guidance and communication systems, stabilization and control, power supplies and other components of space vehicles.

The United States national space program includes a manned satellite project, called Project Mercury. The objective is to begin the manned exploration of space by developing the booster and vehicle technology needed to place a man in orbit about the earth for a short time and recover him safely. By restricting the altitude to a height well below the Great Radiation Belt, discovered by Van Allen, no heavy shielding is required. By planning for only a few orbits before recovery, existing life support systems are adequate and psychological factors are somewhat simplified. In fact, the philosophy adopted is to use the simplest approach based on present state of the art.

There is agreement that the simplest approach is to place the man in a capsule substituted for the nose cone of an ICBM. Figure 13 shows a cross-section of the capsule for which a contract has been let with McDonnell Aircraft Corp. The man is supported in a reclining position on a couch molded to fit his body and located so that the launching acceleration and the deceleration on re-entry will act transverse to the body axis. This system has been thoroughly tested at the United States Naval Air Development Center at Johnsville, Pa., where volunteers have safely withstood accelerations of the order of 20g without injury.

The capsule contains equipment to supply oxygen and remove carbon-dioxide, communications and navigation equipment, attitude control jets, retro-rockets to reduce speed for re-entry, a heat shield to protect the man from re-entry heating, and parachutes for final landing on water.

Safety has been a primary consideration. An escape rocket is mounted on a pylon on top of the capsule to enable ejection and recovery of the capsule in event of failure of the booster system either on the launching pad or in the pre-orbital trajectory.

The operational aspects of tracking and recovery and the proof testing of the capsule and its systems will be developed in steps, beginning with instrumented capsules, animal passengers and, finally, man; first in short ballistic trajectories at low initial speeds; then in several steps at increasing speed until orbiting speed is reached. Only when recovery has been demonstrated on instrumented capsules and with animal passengers with high reliability will the first astronauts make their flights. Figure 14 shows a schematic view of the various occurrences in an orbiting trajectory.

The selection of the first group of space pilots is already in progress so that the selected group may live with the project from the beginning. These men are university graduates, and also graduates of one of the military test pilot training schools, with a minimum of 1500 hours of flight time. They are younger than 40 and not taller than 5′ 11″. They are now undergoing extensive physical and psychological tests. Project Mercury is being pursued with great urgency and with the support of the military services and the Advanced Research Projects Agency of the Department of Defense.

We are beginning a program of practical applications of satellites to peaceful uses, particularly meteorological research and weather forecasting and to communications. At 10.55 am on February 17th, Vanguard II, carrying equipment for studying the cloud cover of the earth, was launched into an orbit with perigee of 335 miles and apogee of 2050 miles. The satellite of Project Score demonstrated some of the potentialities of a communications satellite. These first demonstrations will be followed by a series of successively more sophisticated meteorological and communications satellites. When sufficient booster capacity is available to put large payloads in the 24-hour orbit, we can look forward to extensive use of satellite communications world-wide and of great capacity, including the possible transmission of television programs world-wide. Meteorological satellites will then provide weather observations over the whole earth, over land and sea, to form the basis of more accurate weather forecasts.

Satellites will also be applied to improve methods of navigation and geodetic surveying.

The first satellites constituted a part of the international scientific cooperation of the International Geo-

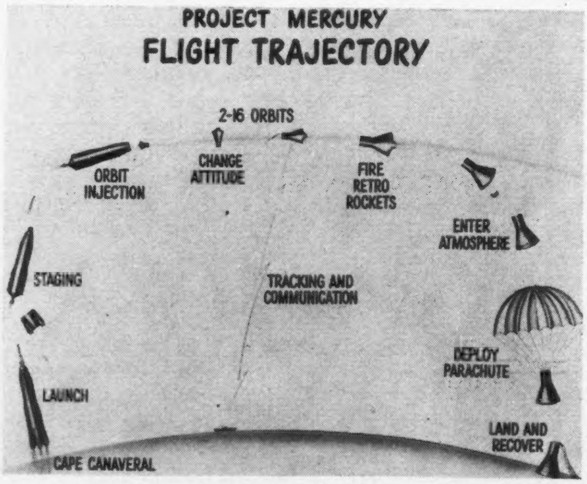

Figure 14
Schematic trajectory for manned satellite mission

physical Year which ended December 31, 1958. Remarkable advances in knowledge of the nearby space environment were obtained with the small scientific payloads of these interim vehicles and all but Vanguard assembled largely from existing components. New phenomena were discovered, of which the most publicized is the radiation belt or belts discovered by Van Allen. From this excellent beginning we are moving forward with an ongoing space science program. Leading scientists in the United States are participating through the Space Science Board of the National Academy of Sciences in formulating the scientific objectives and specific experiments and as associated scientists in the conduct of the experiments. Sounding rockets, satellites, and deep space probes, some aimed to pass near or orbit the moon and planets, are being procured to transport the scientific equipment into space.

The scientific experiments in the established program include as a high priority item the study of energetic particles and their interaction with the earth's atmosphere and magnetic and electric fields. Cosmic ray intensity in interplanetary space, makeup of particles of various energies in the radiation belt, and nature of auroral particles are examples of measurements to be made.

The program for the study of electric and magnetic fields includes satellite and probe investigations with magnetometers out to great distances and in the vicinity of the moon, Mars and Venus. Measurements will be made as close to the sun as possible.

Many features of the atmospheres and ionospheres of the earth and planets are of great scientific and practical interest.

Finally, as booster capacity increases, we can develop orbiting astronomical observatories to study features of the universe in all wave lengths of radiation unmarred by the distortion and opacity of the earth's atmosphere. We can also test the general theory of relativity by comparing the rate of a highly accurate atomic clock in a weak gravitational field far from the earth with that of a clock in the larger field at the earth's surface.

These areas – (1) advance in space technology; (2) beginning of human exploration by manned satellites; (3) satellite applications to meteorology, communications, navigation etc; and (4) scientific study of the space environment by sounding rockets, satellites and deep space probes carrying scientific instruments – indicate the trends. From these we will go on in due course to journeys to the moon and planets and return, to orbiting laboratories and space platforms, and other more difficult space missions. I prefer to stop here with Wilbur Wright in saying that "it is not necessary to look too far into the future; we see enough already to be certain that it will be magnificent."

CONCLUSION

I am today a guest among Canadian friends and it would be presumptious of me to look into the crystal ball for Canada's role in the exploration of space. I am pleased to tell you that NASA and the Department of Defense have concluded arrangements to continue the program of research on nearby space with sounding rockets at Fort Churchill, Canada, which was started during the International Geophysical Year. In addition cooperative research has been arranged between NASA and Canadian scientists using Canadian developed apparatus and experiments. Canadian scientists will also participate in the study of radio transmission from satellites carrying special purpose transmitters. On this note of positive evidence of Canada's entry into space science, I wish to conclude by praising the early enterprise of Canada and its current strong position in aeronautics and expressing the wish that Canada's first steps in the exploration of space are but harbingers of similar great progress in the next half century.

THE CONTENTS OF SPACE NEAR THE EARTH†

by Dr. P. M. Millman*

National Research Council

INTRODUCTION

In any advanced planning for the launching of a manned space vehicle, it is of vital importance to know something of the general physical conditions which are met with in space. In the following discussion we shall restrict ourselves to an examination of the nature of space in the neighbourhood of the earth, since this must be traversed by every space flight. We shall not, however, deal with the properties of the earth's outer atmosphere, magnetic field, or other local effects which the earth impresses on space. Our subject is so-called "empty" space itself, at a position in the solar system corresponding to the earth's mean distance from the sun.

It is convenient to think of the contents of space in three broad categories:

(a) solid particles which are large compared with atomic and molecular dimensions,

(b) atomic and molecular particles, and

(c) electromagnetic radiation.

Both the normal conditions in space and the nature of any large departures from these normal conditions must be investigated. Our information comes from three main sources; surface observation, records made by instruments carried aloft by balloons or aircraft and data resulting from the flights of rockets and earth satellites.

To provide a common ground for comparison of very diverse phenomena we can reduce the observational data to give us approximate values for the contents of space in terms of mass per unit volume and energy per unit volume. We can also list the energy flux across a unit area and the energy of impact with a single particle. In many cases it is only possible to give an estimate of the order of magnitude of these quantities. The tabulated values are in the nature of convenient examples and should be read only in conjunction with a full consideration of the assumptions made in deriving them.

†Paper read at the Special Anniversary Meeting of the C.A.I. in Montreal on the 24th February, 1959.

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Geological Survey of Canada

Figure 1

A typical stone meteorite, ABEE, which fell at 11.05 pm MST June 9, 1952, on a farm fifty miles north of Edmonton, Alberta. This stone is roughly 18 × 15 × 13 inches in size and weighs 240 lb. Before reaching the earth it was observed over a wide area as a brilliant detonating fireball.

LARGE PARTICLES

We will discuss these under three headings in order of decreasing size. This division is not entirely arbitrary but probably has a degree of physical significance.

Meteorites

Meteorites represent relatively large solid fragments that move in low eccentricity orbits around the sun. They are able to survive passage through the earth's atmosphere and their recovery statistics have led to a wide range of estimates of original size and numbers (Figure 1). A conservative figure of 15 meteorites per day for the whole earth[1] has been adopted along with a mean mass estimate of 100 kg per meteorite. This class of objects exhibits densities ranging from stones, 3 to 4 times the density of water[2], up to irons of density 8. Since the stones represent the great majority of the falls over any given period of time, an average density of 4 has been adopted for purposes of discussion. A mean relative velocity between meteorites and earth of 20 km per second has been taken[3], and 30 km per second has been used as the random space

velocity of meteorites at the earth's mean distance from the sun. On the above basis there is one meteorite in each cube of space roughly 25,000 km to a side.

Meteors

The term meteor is used here in a general sense to refer to the solid object which produces the visible phenomenon in our atmosphere. These particles range in size from a weight of about 10^4 gm, corresponding to a visible meteor of stellar magnitude -10, as bright as the crescent moon, through objects of 1 gm, zero magnitude meteors as bright as Vega or Capella, down to small objects 10^{-4} gm in weight, which appear in telescopes as faint moving points of light, stellar magnitude $+10$. Meteors move generally in highly elliptical orbits and there is a considerable body of evidence to indicate that they are loosely-knit structures of denser particles held together by a lighter matrix, a conglomerate that could well be termed a "dustball". No example of this type of object has been known to fall to earth in any form but as dust or smaller units. A mean density the same as water has been used in calculating diameters though the true density may well be an order of magnitude smaller. The smaller meteors are much more numerous than the larger ones, the ratio between successive stellar magnitudes being in the range 3.5 to 4.0 for those brighter than zero magnitude and about 2.5 for those fainter. Integrating down to magnitude $+10$ roughly 2×10^{10} meteors are

Table 1

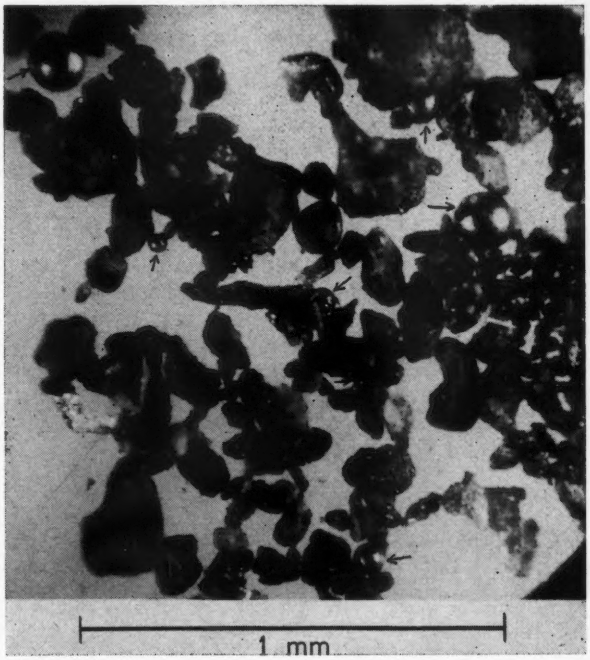
Numbers of Meteors for the Whole Earth

Visual Stellar Magnitude	Daily Total for Single Magnitude Class	Cumulative Daily Total Down to Brightness of Given Magnitude	Min. Mass per Meteor (gm.)
-10	1.5	2	10^4
-5	1.0×10^3	1.4×10^3	10^2
0	7.3×10^5	1.0×10^6	1
5	1.2×10^8	2.0×10^8	10^{-2}
10	1.2×10^{10}	2.0×10^{10}	10^{-4}

encountered by the earth daily[4]. Table 1 summarizes the daily total of meteors encountered by the earth. The summed weight of these objects is estimated as between 1×10^7 and 2×10^7 gm, giving a mean weight per particle about 10^{-3} gm. There is one such particle in every cube 27 km on the side. A mean relative velocity between meteors and the earth of 40 km per second has been used, and this has also been taken as the random velocity of these particles.

Dust

Evidence for interplanetary dust (Figure 2) much smaller than meteors comes from collections made by various methods on or near the earth's surface[5, 6, 7], from records made on satellites and rockets[8] and, indirectly, from a study of the zodiacal light[9]. All these methods agree fairly well as regards the order of magnitude of the total mass falling on the earth. A total of 10^9 gm per day has been adopted here as a fairly conservative figure[10]. The diameters of these dust particles range from a few microns up to 200 or 300 microns. A diameter of 20 microns can be taken as representative and, at density 4, this gives us a particle just over 10^{-8} gm in weight, leading to one particle of this type in each cube 200 metres to a side. A relative velocity of 30 km per second can be taken for this material.



Dr. E. L. Krinov

Figure 2

Meteoritic dust, collected after the fall of the Sikhoté-Aline meteorite on February 12, 1947, in the USSR in a region north of Vladivostok. This dust is magnetic, the major constituent being nickel-iron. The arrows indicate small spherules resulting from a melting and subsequent solidification of the particles.

SMALL PARTICLES

Cosmic Rays

The primary cosmic rays are very high energy, fast moving atomic particles that exist in space throughout our stellar system. The numbers of these particles in the low energy range is not yet very well known but for particles with kinetic energies greater than 10^9 eV we can assume a flux of one particle through each cm^2 per second from one hemisphere[11]. The composition of these rays for particles in the energy range $10^9 - 10^{13}$ eV is roughly

type of particle	*percent by number*
protons (hydrogen nuclei)	91
alpha particles (helium nuclei)	8
nuclei, atomic numbers 3-5	0.1
nuclei, atomic numbers 6-9	0.4
nuclei, atomic numbers $\geqslant 10$	0.2

Mean energy per particle is about 7×10^9 eV or 10^{-2} ergs in round figures. Cosmic ray particles up to extreme energies of 10^{18} or 10^{19} eV have been recorded. There are probably some electrons associated with cosmic rays but within the energy limits given the electron flux is less than 0.6% of the total flux. In computing the space density of cosmic rays it is usual to assume that they move with the velocity of light and that cosmic radiation is isotropic. Any solar component is small, except at the time of major solar flares or other disturbed conditions.

Electrons

Observation of the zodiacal light gives evidence of an electron cloud centred on the sun. It has been calculated that an upper limit for the density of this cloud is 10^3 electrons per cm^3 at the earth's mean distance from the sun[12]. For purposes of discussion we will take one-tenth of this value and consider the mean velocity of these electrons as 30 km per second.

Electron streams

It is known that dense streams of electrons and other atomic particles are shot out from disturbed areas on the solar surface into the portion of the solar system occupied by the terrestrial planets. There is good evidence that fairly high velocities and discrete boundaries are often found in these interplanetary "jet streams". A typical example may be taken as an electron stream with a flux of 10^7 electrons per second across a cm^2 and a velocity of 1,000 km per second between the sun and the earth. Such streams often cause brilliant aurora and magnetic storms in the earth's atmosphere. Under these circumstances the electrons may have 10^4 to 10^5 as much energy per particle as the energy corresponding to the velocity mentioned above. However, it is suspected that some of this extra energy may be added through interaction between the cloud and the magnetic field of the earth. The electrons may also have additional energy due to random motions within the cloud. The energies given in the table should be considered minimum values.

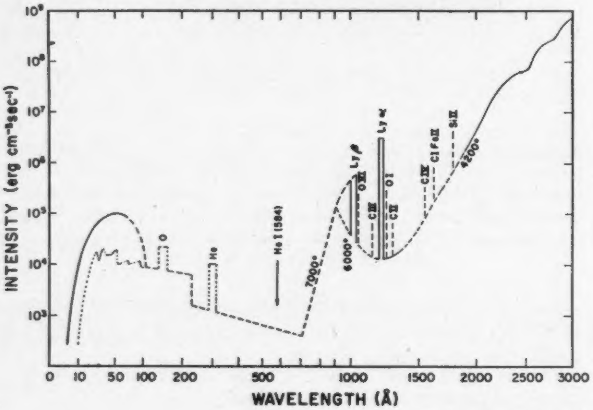


Figure 3

A plot of the intensity of vertically incident solar radiation in the ultraviolet[13]. Wavelengths are listed in angstroms, a unit that is 10^{-8} cm = 10^{-4} microns.

RADIATION

Solar radiation

The predominant radiation in the neighbourhood of the earth is that from the sun, and this includes wavelengths ranging all the way from gamma rays less than 10^{-8} cm in length up to radio waves many km long. The integrated intensity of all these wavelengths gives us a flux of just under 2 calories across each cm^2 per minute. We will adopt 1.38×10^{10} ergs per m^2 per second as the average value of the solar constant. This varies from the mean by 1% or 2%, depending on the current activity in the sun. The variation of solar radiation with wavelength has been discussed recently by K. Watanabe[13] for the ultraviolet region (Figure 3), by S. F. Singer[14] for the visible and infrared (Figure 4) and C. W. Allen[15] for the radio wavelengths (Figure 5). The largest percentage of the energy is received in the visible part of the solar spectrum, the distribution being approximately as follows:

wavelength (cm)	*energy (%)*
$< 3 \times 10^{-5}$	0.2
$3 \times 10^{-5} - 10^{-4}$	71
$10^{-4} - 10^{-3}$	28
$> 10^{-3}$	0.7

The general distribution of solar radiation with wavelength is illustrated in Figure 6.

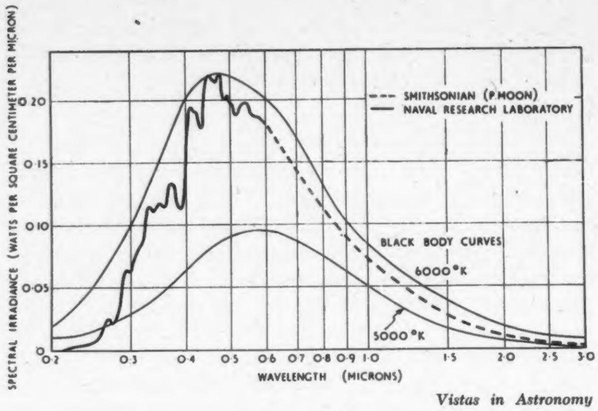


Figure 4

The solar spectrum curve in the visible and neighbouring wavelength ranges[14]

Stellar radiation

Stellar radiation is also present, but in much smaller quantities than the solar radiation. It is roughly isotropic, coming from all parts of the galaxy though there is a tendency for there to be more from near the plane of the Milky Way. The energy content of space for stellar radiation is taken as 10^{-8} that for solar radiation.

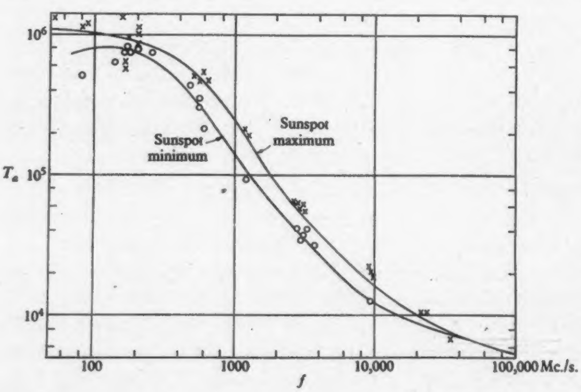


Figure 5

Radio radiation from the quiet sun, plotted in units of apparent temperature, T_a, against radio frequency in megacycles per second[15]

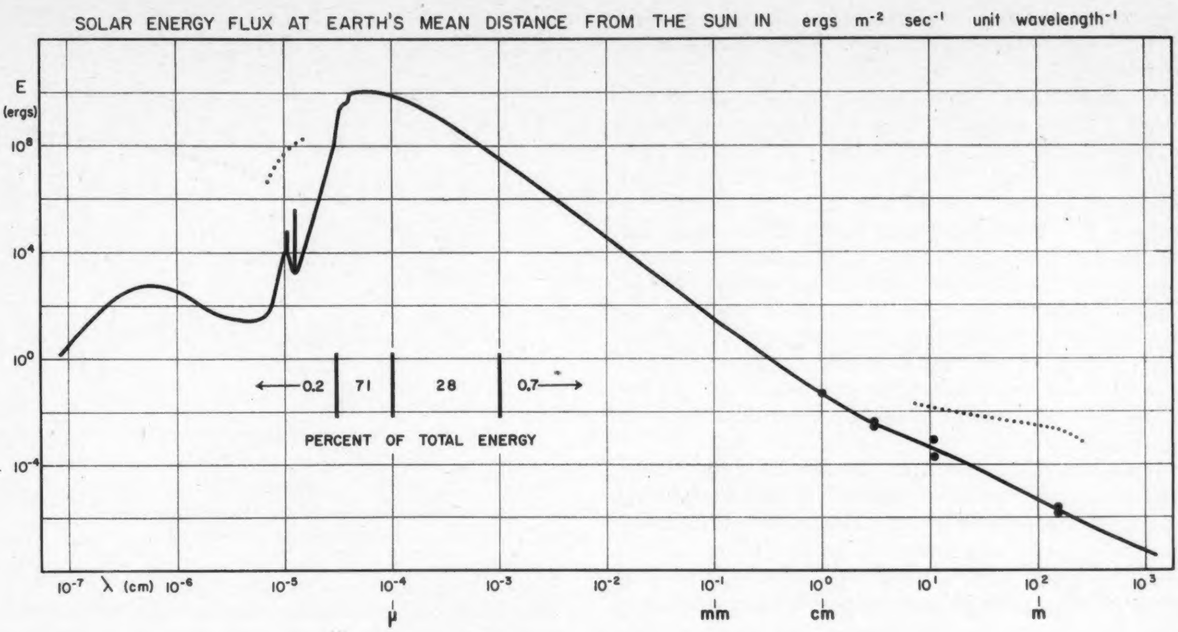


Figure 6

Data for the above curve has been taken chiefly from Watanabe[13] for wavelengths below 0.3 microns, from Singer[14] for the range 0.3 to 10 microns, and from Allen[15] for the radio wavelengths. High and low points in the radio range refer to conditions at sunspot maxima and minima respectively. The emission of the Lyman α and Lyman β lines of hydrogen is indicated in the ultraviolet near 0.1 micron.

The dotted curves indicate very approximately the increases in solar radiation possible at the periods of intense solar flares. Since the flux has been plotted at each point for a band-width equal to one wavelength this, when taken with a logarithmic scale of wavelength, gives a plot which is linear in regard to energy along the horizontal axis. The flux integrated over all wavelengths is 1.38×10^{10} ergs m^{-2} sec^{-1}.

CONCLUSION

Using the assumptions mentioned above certain quantities have been calculated and listed in Table 2. The masses given in brackets for category (b) refer to the rest mass. The mass content of space in category (c) lists the mass equivalent to the radiation, using the equation $E = mc^2$. The energy flux listed is found by integrating over one hemisphere in all cases except for electron streams and solar radiation. The particle impact energies are computed assuming collisions at the random velocity. This table is meant to refer to average conditions but it does not necessarily contain all the particles, radiation or other properties which should be taken into consideration. For example the high energy radiation in the Van Allen belts, recently detected by instruments on artificial earth satellites, has not been included as it

TABLE 2

SOME PROPERTIES OF SPACE AT ONE ASTRONOMICAL UNIT FROM THE SUN

		Particle Mass (gm)	Particle Diameter (cm)	Volume Containing One Particle (cm^3)	Mass per Unit Volume (gm cm^{-3})	Energy per Unit Volume (ergs m^{-3})	Energy Flux (ergs m^{-2}sec^{-1})	Particle Impact Energy (ergs)
(a)	Meteorites	1×10^{5}	4×10^{1}	$1\frac{1}{2}\times10^{28}$	7×10^{-24}	3×10^{-5}	2×10^{-1}	4×10^{17}
	Meteors	1×10^{-3}	1×10^{-1}	2×10^{19}	4×10^{-23}	4×10^{-4}	4×10^{0}	8×10^{9}
	Dust	2×10^{-8}	2×10^{-3}	7×10^{12}	3×10^{-21}	$1\frac{1}{2}\times10^{-2}$	1×10^{2}	9×10^{4}
(b)	Cosmic Rays	(2×10^{-24})		7×10^{9}	3×10^{-34}	1×10^{-6}	1×10^{2}	1×10^{-2}
	Electrons	(1×10^{-27})		1×10^{-2}	1×10^{-25}	4×10^{-7}	3×10^{-3}	4×10^{-15}
	Electron Streams	(1×10^{-27})		1×10^{1}	1×10^{-28}	4×10^{-7}	4×10^{-1}	4×10^{-12}
(c)	Solar Radiation				(5×10^{-26})	5×10^{1}	$1\frac{1}{2}\times10^{10}$	
	Stellar Radiation				(5×10^{-34})	5×10^{-7}	4×10^{1}	
	In Galactic Plane: Turbulent Energy					$1\frac{1}{2}\times10^{-6}$		
	In Galactic Plane: Magnetic Field Energy					$1\frac{1}{2}\times10^{-6}$		
	In Galactic Plane: Thermal Gas Energy					$1\frac{1}{2}\times10^{-6}$		

seems likely that this is controlled by the magnetic field of the earth rather than being a typical property of space itself.

It will be noted that in category (a) the smaller particles are more important both from the standpoint of the mass content and energy content of space. In category (b) the energy flux of cosmic rays is high relative to their energy and mass density. The solar radiation in category (c) is the dominating factor in the entire flux column. For comparison, three other sources of energy in space are listed for average conditions in our galaxy, without taking into account proximity of the sun. To compute the turbulent energy a density of 10^{-24} gm per cm^3 was used. If the same turbulent conditions exist in the neighbourhood of the earth at density 10^{-21} gm per cm^3 the turbulent energy would be more than 10^3 times the amount listed.

It remains to consider the deviations from average conditions which may be expected. The flux of meteorites is a scattered phenomenon but seems to vary little in the average frequency of occurrence. In the case of meteors the flux may rise to 10^3 or even 10^4 the normal value at the centre of a compact meteor stream moving along a cometary orbit (Figure 7). The dust flux does not vary appreciably. Primary cosmic ray flux may vary by a few per cent but is essentially constant as far as is known. The electron and heavy particle streams from the sun show a wide range in flux intensity and more exact information on this subject should be available after all the International Geophysical Year observations have been correlated. The solar radiation does not vary much in total amount but the flux of short wavelength radiation near 10^{-5} cm and long wavelength radiation near 10^2 cm may increase during solar flares by factors of 10^2 or 10^3. Stellar radiation is very uniform but would be greatly modified if we had a super-nova outburst not too far from the position of the sun in the galaxy.

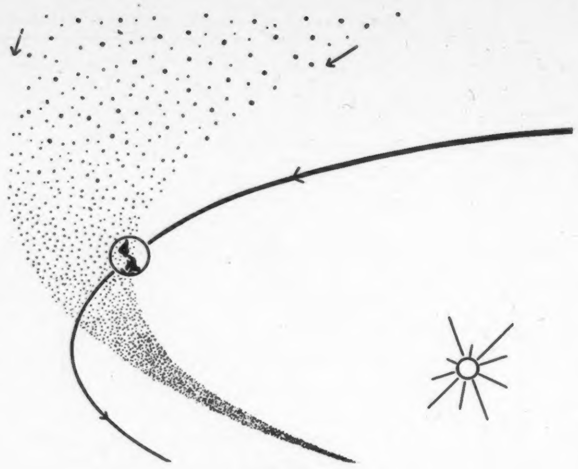


Figure 7
The passage of the Earth through a concentrated meteor orbit

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A CANADIAN VIEW OF RECENT DEVELOPMENTS IN AERODYNAMIC RESEARCH†

by R. J. Templin*

National Aeronautical Establishment

SUMMARY

Recent developments in aeronautics indicate that flight is possible and, in some circumstances, may be economically sound over an extremely wide range of design speeds. A few of these possibilities will be reviewed, including vertical takeoff aircraft which must be capable of hovering flight, and boost-glide aircraft which may cruise at speeds approaching satellite velocity.

Some of the aerodynamic research problems which have been raised by these developments will be discussed, with particular reference to possible future Canadian needs.

INTRODUCTION

THE celebration of the 50th Anniversary of heavier-than-air flight in Canada is an appropriate time to look both backward and forward, to see how far we have come and to consider the future prospect.

Only a small amount of reflection shows that we have come a long way in aeronautics since those early days. It is also apparent, however, that we are now at a critical time and it is not clear where we go from here, at least as far as aircraft development is concerned.

One thing is fairly clear: aviation has played a very large part in Canada's development and it is almost certain to play a large part in its future.

Those engaged in research must be particularly concerned with the future, because research must go hand-in-hand with development, and the planning of facilities and applied research programmes must take into account possible future requirements.

In aerodynamic research, experimental facilities are expensive and a country the size of Canada cannot afford to build very many. They also require several years to design and build in some cases, and tend to have a useful life of 10 to 20 years. This makes it all the more important that appropriate plans are made.

There is another factor which may become important in the future. Aircraft companies in the smaller countries, such as Canada, have been able, in the past, to draw almost all of the necessary research information from the output of agencies in the large countries, such as the United States and the United Kingdom. But, recently, a large fraction of the effort in these countries is being diverted to space flight and long range missile research and development. This may mean that in the future the smaller countries will have to be more self-reliant in the pursuit of aeronautical research.

It is fully realized that any attempt to guess the areas of *likely* future aeronautical development in Canada would have to take into account factors other than purely technical ones. Others are more competent to judge these things and, therefore, the guesswork which is to follow will only be concerned with *possible* developments and requirements, since this is about all that can be discussed from a purely technical viewpoint.

Furthermore, this guesswork will be confined mainly to the question of manned aircraft requirements for several reasons. In the first place, the missile picture in Canada seems to be particularly cloudy at the moment; it may be easier to make predictions in a few years' time. Secondly, we are going to discuss some of the aerodynamic problems requiring research effort, and these appear to loom larger in the development of aircraft than in missile development. Finally, the aerodynamic research facilities which may be available for one purpose can very likely be used for the other, provided they cover the right speed ranges.

TRENDS IN SPEED

It is obvious, even to the uninitiated, that one of the most significant trends in aeronautics throughout its brief history has been the rapid increase in flight speed of

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†Paper read at the Special Anniversary Meeting of the C.A.I. in Montreal on the 23rd February, 1959.

*Head, Aerodynamics Section

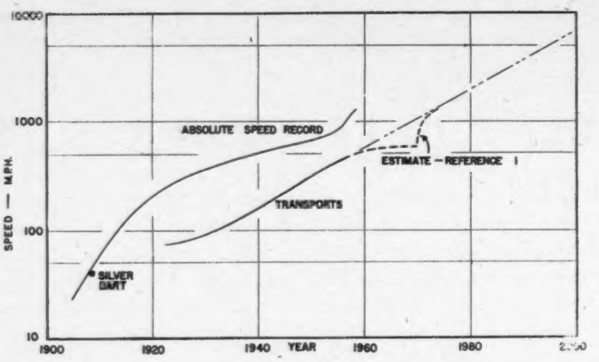

Figure 1
Speed of manned aircraft

nearly all aircraft types. This is summarized in Figure 1, which is replotted, using a logarithmic speed scale, from data given in Reference 1. A point representing the flights of the Silver Dart at Baddeck in 1909 has been added.

Up to the present time, increases in speed (speed records and speeds of transport aircraft) have been very roughly exponential, with speeds doubling approximately every ten years.

This is only roughly true, and it is interesting to note that if anyone had attempted to make a prediction on this basis in about 1920, using the previous 15 years' records, they would have said that aircraft speeds should be hypersonic by about 1940. The early pioneers indeed made progress in large steps.

An exponential prediction, based on the past 40 years of progress, indicates flight at Mach numbers of 10 or more may be reached by transport aircraft by the turn of the century. In general, the speeds of transport aircraft seem to lag about 15 or 20 years behind the absolute speed record.

The speed trend is illustrated in another graphical form in Figure 2. This shows the so-called "flight corridor" and is a fairly common chart these days, because it is a concise way of illustrating how increases in altitude accompany increases in flight speed so that the temperature problem can be held at arm's length while sufficient lift is developed. The area labelled "Too Slow" is that in which the dynamic pressure is too small for the production of lift at moderate wing loadings. The area labelled "Too Hot" indicates that frictional heating is too severe for presently known materials, without heavy cooling equipment.

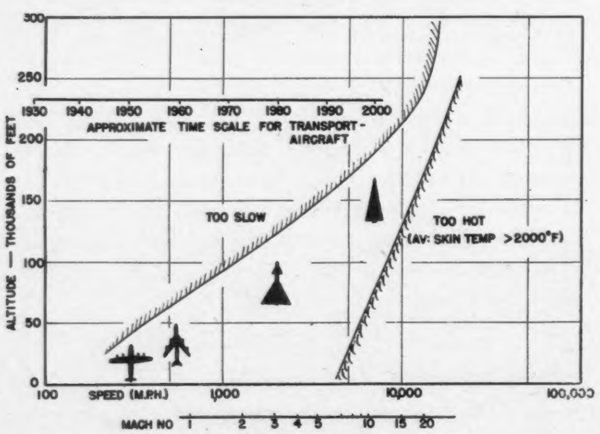

Figure 2
The atmospheric flight corridor

This chart looks a little different from the form usually used, because of the logarithmic speed scale. We have previously seen that, in the past at least, such a scale roughly corresponds to a time scale. It is probably going too far out on a limb to do this, but an extrapolated time scale from Figure 1 has been inserted on the chart, appropriate to transport aircraft.

The implication in showing this diagram with a transport aircraft time scale is that operating costs can be kept down to useful values even at extreme flight speeds. There have been recent suggestions from a number of quarters that this can be done. An excellent paper which discusses the question is the Twenty-First Wright Brothers Lecture, delivered in Washington by Mr. H. Julian Allen[2] about a year ago. One of the conclusions reached in that paper was that the ballistic vehicle can compare favourably with the supersonic aeroplane for long and short range flight, and the hypersonic rocket boost-glide vehicle may also prove to be attractive.

Less obvious, but perhaps equally significant, is the trend toward the reduction of minimum flight speeds for certain types of manned aircraft. Increases of runway lengths have accompanied the steady increase in cruising speeds, so that airports must be built further and further from city centres. By the turn of the century, it may be possible to fly from Montreal to Vancouver in half an hour, but it already takes twice that long to get from downtown Montreal to Dorval airport. This and other problems which will be discussed more fully in the next section have recently generated a great deal of activity in the vertical takeoff field. A truly economical vertical takeoff aircraft could greatly change some aspects of the military and civil air transportation field.

To summarize, it is probably true to say that the most significant recent trend in aeronautics, at least as far as the aerodynamicist is concerned, is the pressure to greatly widen the range of atmospheric flight speeds, both upward and downward.

POSSIBLE CANADIAN REQUIREMENTS

We have already seen that we might expect to see commercial transport aircraft flying in the extended supersonic speed range in approximately 20 years, and hypersonic transports in about 40 years. Very shortly in the United States the first manned flight in a research aircraft will be made at what might be called low hypersonic speeds, that is, at Mach numbers a little above 5, and development has started of a hypersonic boost-glide military aircraft.

In the opposite direction along the speed scale, the recent activity to develop useful short takeoff and vertical takeoff aircraft for military and civil purposes has been mentioned. But to anyone engaged in aeronautics in Canada there are a number of questions which are not easy to answer.

(a) What are the possible future requirements for aircraft in Canadian operations?

(b) Would any of these requirements justify Canadian development?

(c) In the various specialized fields, and in particular in the field of aerodynamics, what type of applied research should be carried out in the future to best meet possible Canadian needs, and in order to keep abreast of developments elsewhere?

These questions cannot possibly be answered in a complete way here because, as was pointed out at the beginning, there are factors involved which are not purely technical. Even the technical aspects require a considerable degree of crystal-gazing. However, the researcher in aerodynamics must be concerned with possibilities rather than probabilities, and so as long as we are content to discuss *possible* (as distinct from *likely*) future trends and requirements, we may be able to arrive at some tentative conclusions.

The range of possible future aircraft requirements in Canada appears to be very wide indeed.

In the military sphere it appears that armed aircraft will continue to be needed for such roles as the support of ground forces and ocean reconnaissance, even if events prove that the manned interceptor is no longer required in large numbers. At the present time the supersonic interceptor and its successor, the manned hypersonic interceptor, cannot be completely ruled out on technical grounds alone. Unarmed military aircraft are likely to be required for transportation purposes, especially in support of mobile ground forces, and there may even arise a requirement for a high speed northern reconnaissance and identification aircraft. A successful vertical takeoff aircraft may have a profound effect on military aircraft as a transport and as a partial replacement for wheeled vehicles in the battle area.

In the civil field as well, the vertical takeoff aircraft could play an important part. The recent Royal Commission on Canada's Economic Prospects has pointed out that air transportation in Canada and the United States carries much less than one-half of one per cent of the ton-miles of freight transported on the railways, and they have estimated that the amount will probably increase by about four times in the next 20 years. But, to quote from their Final Report[3], "if the helicopter principle is ever successfully adapted to fixed-wing jet aircraft for purposes of takeoff and landing, the future growth of air transport would be enormously greater than we have estimated".

It has also been pointed out, in a paper[4] before the Ottawa Branch of the CAI about two years ago, that the vertical takeoff aircraft could play a valuable role in the future development of Northern Canada. All of the North is within 250 miles of airfields which are suitable for supply bases, but only a small fraction of this vast area can be reached from these same bases by a fully loaded helicopter with a radius of, say, 50 miles.

Commercial airline operations in Canada and on international routes can be expected to expand rapidly in the future, as in the past, and the airlines are likely to continue to operate the most modern available aircraft. It may therefore be assumed that there will arise in the future, perhaps by about 1970, a Canadian requirement for a supersonic transport aircraft. Would this requirement be large enough to justify a Canadian development, taking into account at the same time the possible needs in the military transport field? Even this possibility seems hard to rule out, and it is seriously suggested that it should be investigated by the competent aircraft companies.

Figure 3 shows a plot of the growth of Trans-Canada Air Lines passenger traffic during the past 13 years or so. The curve has been extrapolated, taking into account an estimate given in Reference 5 of the traffic expected in 1956. The extrapolated curve indicates that, by about 1970, the level should rise to about 10 billion revenue passenger miles per year on Canadian domestic and international routes. This is equal to the world total for all airlines in 1946. The traffic which can be handled by a single aircraft also rises with time, of course, because of the increase in aircraft size and speed, but these statistics indicate a market in Canada for an increased number of passenger-carrying aircraft in the next 20 years or so. It may be that Canadian requirements by that time would call for a high performance aircraft of only moderate seating capacity, because it has been pointed out in Reference 5 that the frequency of flights on most of the domestic routes is considerably below the optimum frequency, and that the desirable frequency increases as flight time is reduced.

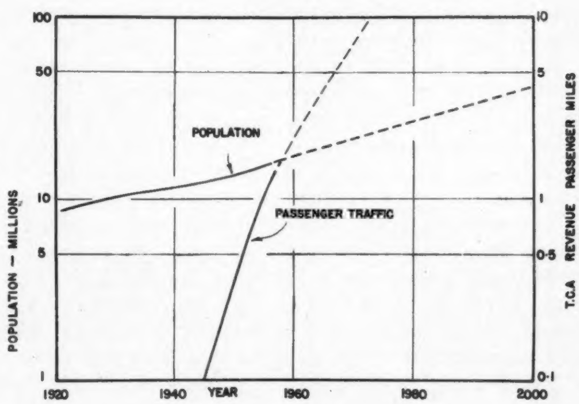

Figure 3
Growth of population and airline passenger traffic in Canada

Also plotted on this graph, just for comparison, is the population growth in Canada, together with an extrapolation to the year 2000. The extrapolation is based partly on the estimation of the Royal Commission referred to previously, which predicted a population of about 27,000,000 by 1980.

AERODYNAMIC RESEARCH PROBLEMS

Vertical takeoff problems

Let us now consider the appropriate avenues of research in aerodynamics which seem to follow from our crystal-gazing about possible future requirements.

The reasons have been given for believing that there may be future requirements, both military and civil, for vertical takeoff aircraft on the Canadian scene. In some

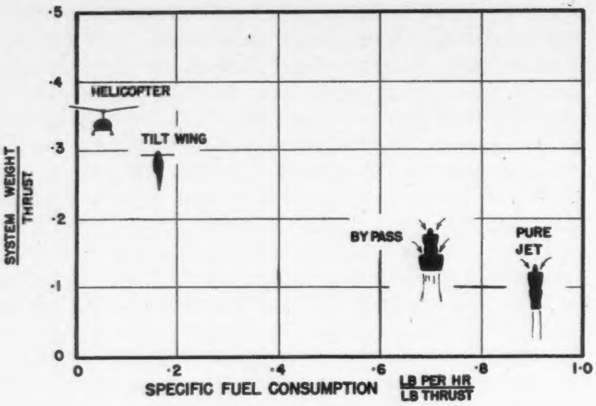

Figure 4
Comparison of vertical takeoff systems

cases these requirements would arise simply because there may be no other form of transportation available which can do the same job. But there are other situations in which such aircraft might be expected to compete economically with alternative forms. In either case, it is desirable that any aircraft, including VTOL aircraft, should be as economical as possible to buy and to operate. This ideal has not been reached.

Rather than review the complete list of aerodynamic problems inherent in the development of efficient VTOL aircraft, I would like to mention just one or two things which may sometimes tend to get overlooked in a mass of detail, and which could in themselves lead to useful and interesting research programmes.

The ability to hover, to remain stationary in mid-air, is not a process which theoretically need require the expenditure of any energy at all, since no useful work is done. There is, in fact, one class of vertical takeoff vehicle which comes close to realizing this ideal: the balloon or dirigible. Perhaps this type of transportation vehicle died out too soon, before it had a real chance to show itself to best advantage. However, that is not the point of this discussion. The fact is that nearly all of the methods now proposed for producing a large vertical force at zero flight speed require the expenditure of so much energy that they impair the performance of the aircraft in other ways. Usually several times more powerplant weight and other gadgetry must be installed than is required for efficient cruising flight so that dead weight is carried around most of the time, which can be translated into lost payload or range.

The lifting powerplants capable of producing the largest thrust per pound of installed weight also happen to be the ones with the most alarming fuel consumption. This is illustrated in Figure 4, which shows four different lifting schemes. A rough calculation based on this graph will show that for around 10 or 15 minutes of full-power operation, during which a thrust equal to aircraft weight is produced, all of the devices shown are comparable, but the total weight of the thrust-producing system plus hovering fuel is around 25% or 30% of the aircraft weight. This means that a vertical takeoff aircraft, based on one of these principles, which can carry a reasonable payload will be restricted to relatively short ranges and will be comparatively expensive to buy and to operate. To do a job that cannot be done any other way, this sort of thing may be acceptable, but it hardly seems to be a solution to the problem of providing a vehicle that is competitive in the air freight business, or which can solve the airport problem for long-range, high speed transports of the future.

In view of the drawbacks which still remain it would appear that vertical takeoff aircraft development is still in its infancy. Is there any way around the problem just outlined? This is difficult to say; there may be an avenue or two worth exploring although these could turn out to be blind alleys. The pure jet engine is a light weight powerplant for the thrust produced and is efficient in high speed flight. However, the thrust required for vertical takeoff, including allowances for safety and non-standard conditions, is so much greater than the cruising thrust required that, for a subsonic jet transport, at least four times as much powerplant would have to be installed for takeoff as is required for cruising. The specific fuel consumption is also high so that the pure jet is an inefficient hovering powerplant. Both problems would be solved if a simple, light-weight method could be found to transfer the high energy of a jet efficiently to a large mass flow of air. Is there a way to augment the momentum of a jet by a factor of about four using purely aerodynamic means? This is a nice problem, possibly worth basic research effort.

There is a way to augment the thrust of a jet by the use of additional moving parts in the form of turbines and fans. Preliminary weight estimates indicate that gas-driven fans buried in an aircraft wing may produce sufficient thrust for takeoff for a weight which is about the same as the weight of pure jet engines which would be required to do the same job. In this case the basic engine is still a turbojet but its size can be matched to cruising requirements. This scheme does not necessarily save powerplant weight therefore, when compared with the pure jet lift scheme, but it provides relatively low hovering fuel consumption. The fan-lift scheme is therefore being considered in a number of places.

Another interesting aerodynamic aspect of most of the proposed systems is that during low speed transition flight the flow past the aircraft is characterized by two airstreams of greatly different energies. The interactions between the lift-producing flow and the main airstream can produce many odd effects, differing in the different aircraft proposals, but all difficult to predict at the present time.

For example, wind tunnel tests have shown that a fan buried in a wing induces pressures over the wing which add to the total lift, but which are centred so far forward that large nose-up pitching moments result. As a matter of fact, recent attempts to calculate these effects have been moderately successful, and the results of one such calculation are shown in Figure 5. Here the calculation is compared with experimental results obtained by pressure-plotting a wind tunnel model. The theory used is simply a lifting-surface theory in which the wing (including the fan hole in this case) is represented by a large number of horseshoe vortices with the induced velocities

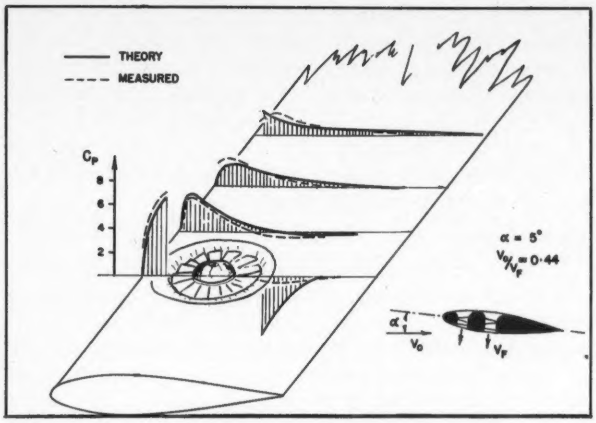

Figure 5
Lift distribution on an aerofoil with buried fan

specified everywhere by the wing angle of attack and the velocity pumped through the hole by the fan. The problem was solved with the aid of a digital computer. The method should be applicable to all wing plan forms with camber and twist, and to multiple fan installations.

Similar aerodynamic problems exist with other vertical takeoff systems, including those in which propeller slipstreams are present. Insufficient detailed experimental work has been done to provide the aircraft designer with quantitative design information or with a theoretical framework from which accurate aerodynamic calculations can be made. It appears that, in the low speed aerodynamics field, this is an area in which Canadian research should be continued.

High speed aerodynamics

The question of appropriate areas for applied research in high speed aerodynamics is more difficult to discuss because the field is very broad, and the prospects for future Canadian developments in this field are less clear. However, it has been pointed out that there are several possible military requirements for high speed aircraft, and that in about 20 years or so even transport aircraft may be expected to have reached cruising speeds in the extended supersonic speed range.

Developments in this field of aerodynamics have been rapid during the post-war period and we have seen how the speed range available for efficient flight has been extended, approximately in an exponential fashion. Applied research effort is essential, to keep abreast of developments elsewhere and in order to ensure that facilities are available for development testing when the need for them arises.

To a large extent, advances in the propulsion field have been responsible for the rapid increases in flight speeds. Air-breathing powerplants appear to be capable of efficient operation up to Mach numbers of at least 5, and the performance of rocket propulsion systems is nearly independent of speed and ambient air density. However, a great deal of applied research in aerodynamics remains to be done in order that the advantages of these methods of propulsion can be fully realized.

For efficient flight in the extended supersonic speed range, the main aerodynamic requirement is the achievement of good lift/drag ratios, for the same reasons that have always been applicable at subsonic speeds. In fact the familiar Bréguet range equation provides a simple way of showing the relative importance of the different factors. For sustained level flight it can be written:

$$R = (L/D)\, I\, V \ln\left(\frac{W_i}{W_f}\right)$$

where R = range
L/D = aerodynamic lift/drag ratio in cruising flight
I = propulsion system specific impulse (inversely proportional to specific fuel consumption)
V = flight speed
W_i = initial weight of aircraft at beginning of cruising flight
W_f = final weight of aircraft at end of cruise, after fuel is expended.

The required value of the ratio W_i/W_f in order to achieve a specified range R is a measure of the efficiency of flight. The specific impulse I will depend on the type of powerplant and will also be a function of speed, so that for any given type of propulsion system the product IV will depend on the cruising speed V. An interesting discussion of these factors, together with a summary of typical values of I and IV, is given in Reference 2.

In order to show, in a more quantitative way, the importance of achieving a high aerodynamic standard, Figure 6 shows the results of a calculation of the ratio W_i/W_f for a Mach 4 turbojet aircraft as a function of the lift/drag ratio achieved, for a specified range of 3,000 nautical miles. In this calculation a value of 800 nautical miles was assumed for the product IV, as suggested by the data of Reference 2. The importance of achieving

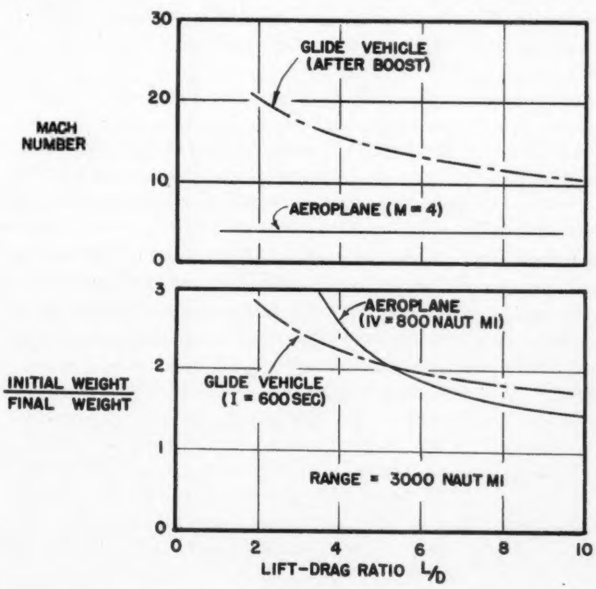

Figure 6
Effect of lift/drag ratio on characteristics of a supersonic aeroplane and hypersonic glide vehicle

lift/drag ratios of 5 to 10 is apparent from this graph if ranges of the order of trans-Atlantic distances are to be achieved.

Also shown in Figure 6 is the corresponding curve for a hypothetical boost-glide vehicle. The specific impulse assumed (600 seconds) is about twice as large as presently obtainable values for rockets, but is considered to be obtainable in the future. Rocket propulsion suffers the disadvantage that all of the mass required for its operation must be carried aboard the vehicle. On the other hand this disadvantage is partly offset in the boost-glide vehicle, which coasts a long distance after a relatively short period of acceleration to high speed. For very long ranges the required speed at burn-out approaches satellite velocity and in this case the achievement of aerodynamic efficiency is not very important. For the case actually calculated (3,000 nautical miles range) the required weight ratio varies less rapidly with lift/drag ratio than in the case of the supersonic aeroplane, but the importance of achieving high values is still apparent. In fact, high values of the lift/drag ratio not only make the boost-glide vehicle comparable with the aircraft in weight ratio, but they also reduce the maximum speed of the vehicle at the end of boost, thus relieving the aerodynamic heating problem.

It is by no means clear that it will be easy to achieve lift/drag ratios between 5 and 10 at high supersonic and hypersonic speeds, and research in this direction is likely to continue indefinitely because of its importance. In particular, experimental work at high Reynolds numbers and at Mach numbers extending up to about 5 will be of great importance in the immediate future. A wind tunnel facility is now under construction in Canada which will provide approximately full scale Reynolds numbers over this speed range, and the opportunity will exist for making useful research contributions in this field.

Direct application in Canada for the results of research at hypersonic speeds is undoubtedly a more remote possibility. However, a limited amount of experimental research appears to provide the only satisfactory way of keeping abreast of rapid developments taking place elsewhere. For some time now the development of hypersonic free flight range techniques has been under way at the Defence Research Board's armament research establishment at Valcartier, and a small hypersonic wind tunnel is being constructed at the National Research Council in Ottawa.

Mention has been made so far of only one aspect of high speed research: the performance problem, or the necessity to achieve high lift/drag ratios. There are, of course, many others. As flight speeds increase, the boundary line between aerodynamics and structures becomes less distinct due to the increased importance of aeroelastic effects, and the effects of aerodynamic heating on structural design. The whole field of aerodynamic stability is becoming more complex as well. Considerable experience has been accumulated in Canadian research establishments on the methods of measuring dynamic stability characteristics of aircraft and missiles at high speed. It is hoped that these methods can be further developed for use up to the hypersonic speed range.

CONCLUSION

The most significant trend likely to affect the future course of aerodynamic research seems to be the rapid widening of the speed range available for efficient aircraft flight. Minimum flying speeds are being reduced to zero by research on short takeoff and vertical takeoff aircraft problems, and flight at hypersonic speeds is no longer considered to be beyond the realm of possibility, even for transport aircraft.

Although it is extremely difficult to predict the course of future Canadian aircraft development, it appears likely that a wide range of aircraft types will continue to be required for military and civil use in Canada. There is even a possibility that the Canadian development of a medium-capacity supersonic transport should be seriously considered. It is therefore concluded that applied research should be pursued in a number of areas.

In the field of aerodynamics, it appears that applied and basic research should be continued on the problems associated with vertical takeoff aircraft. Satisfactory solutions to some of these problems are not yet at hand. When new wind tunnel facilities are completed there will be opportunities to make contributions to a major current and future problem: the achievement of high lift/drag ratios throughout the "air-breathing" speed range, up to Mach numbers of about 5. Limited research at hypersonic speeds should be carried out, in order to keep abreast of rapid developments in this field. Experience already gained in the dynamic testing of models in free flight and in wind tunnels should be extended to this speed regime.

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OPERATIONS RESEARCH — SOME AIRLINE APPLICATIONS†

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SUMMARY

There has been no radical change of procedure for aircraft operation and maintenance for the past twenty-five years. With the advent of turbine powered aircraft, the time is rapidly approaching when a new approach will be imperative if an airline is to stay in competition.

It is hoped to show that the problems of airline operation, since many of them are essentially quantative, can submit to the analytical methods of the physical sciences. It is sincerely believed that in many areas operations can be represented, and therefore optimized more efficiently, through the use of mathematical models or the process of system simulation using the computer. Further, it is hoped to show that the services of a properly trained research team, us'ng new operations research tools for problem solving, will repay senior management by providing reliable information for sound predictions and decisions.

INTRODUCTION

OPERATIONS Research can be summed up in one word — *Totality*.

It became quickly apparent that if this concept was to be set as the main objective of the paper, then, in the space allowed, it will be possible to deal with the subject only in the broadest terms.

With such parameters, the major pitfall is that of superficiality. The writer greatly fears that such a criticism might well be levelled. The best that can be said against this criticism is that an honest attempt was made to avoid it. At the same time, the writer assumes a basic familiarity, on the part of the reader, with certain airline terms, procedures and systems, in order to abbreviate the presentation.

The advent of multi-engined, pressurized, high performance aircraft, equipped with all manner of complicated electronic devices and navigational aids, brought to the airline business another "Industrial Revolution". The post-war years have seen the introduction of new systems and procedures, such as reservations control, production control, inventory control and cost accounting, to mention a few. Complementing these changes has been the introduction of data processing through the use of electronic machinery and, latterly, the computer. It is submitted that these have been changes of technique rather than basic approach. With the rapid growth and expansion of the progressive airline, there has arisen a pressing need for *coordination, integration and optimisation.*

With the introduction of turbine powered aircraft, attended by their appreciably higher capital investment and operating cost, optimum utilization of equipment is of even greater concern. It is submitted that the time is rapidly approaching, if not already here, for the airlines to adopt a new approach, an approach which considers all phases of company operation, and integrates them with the common aim of maximum effectivity and economy. In a word, a coordinated total approach is required.

OPERATIONS RESEARCH — A DEFINITION

Operations Research has been called many things, but the most revealing definition that the writer has come across is that used in a paper by Goland and Koenigsberg[1]:

"Some people call it scientific commonsense. Others describe it as a scientific philosophy. All agree on its fundamental scientific nature. Operations Research is the name applied to the scientific study and analysis of management problems aimed at maximizing or optimizing effectiveness of a company's overall operation.

"To study and analyze these problems, the operations researcher draws upon the methods of the basic sciences and the results of the applied sciences. His chief tools are mathematics, the experimental model, the observed data and objectivity. His subject is company operations; not one particular phase of operations, but total operations considered as an integrated economic unit. His goal is the company's goal: the most effective total operation. Validity of his results is the validity of the scientific experiment: can it be repeated? Or, as a corollary, can it be used to predict future courses of action?

"The basic assumption of the operations researcher is that all effects have corresponding causes. He uses intuition, commonsense, judgment and technical skill to

†Paper based on a talk given at the First I.A.T.A. Technical Conference in London, on the 19th May, 1958.

*Superintendent of Planning.

reduce data to its workable components wherein he seeks the key to understanding the fundamental mechanism of the operation."

INDUSTRIAL ENGINEERING — AIRLINE APPLICATIONS

The past five years have seen the growth of a new function, a new occupation, that of Industrial Engineering; sometimes referred to as the "mechanics of management". Operations Research has been described as the basic science of the applied science of Industrial Engineering. Operations Research has a purpose similar to that of Industrial Engineering, to provide information for sounder decision-making. The difference between the two may be said to be largely a matter of degree.

Industrial Engineering has been applied extensively in the airline production field. The reason is quite simply because approximately one-third of airline operating costs are spent in the maintenance of aircraft. The production planner is singularly fortunate in being required to take into detailed consideration the effect of his plans on other departments and divisions, thereby obtaining an overall picture of the airline operation – a picture not often granted to the majority of his colleagues. His function at its best involves an underlying integration of flight schedules, maintenance schedules, inventory control and cost accounting. The totality concept is by no means foreign to him or new to the industry. The concept has been practiced by the military for a number of years; a notable example is described in a paper by S/L E. A. Harrop[2] in 1949, and has been more recently propounded most effectively by Heinrich[3].

A condition which is felt acutely at times is that all too frequently detailed plans and scheduling at the production control level are seriously disrupted due to the lack of planning on a higher and broader level. This is undoubtedly due to the lack of factual information. Perhaps we shall see before the close of this paper the means whereby certain additional vital information can be obtained.

When the time comes for Operations Research to be an accepted management technique in the airlines, it will be the industrial engineer to whom the operations researcher will turn for the seeds from which airlines Operations Research can grow. Typical of these seeds will be such procedures as forecasting, scheduling and control; flight scheduling, aircraft routing; progressive overhaul and component repair schedules; labour and material standards – work sampling, methods analysis; statistical quality control; and cost analysis and control.

OPERATIONS RESEARCH — AIRLINE OPERATIONS

The writer confesses to an abysmal ignorance of the finer points and techniques of Operations Research. He is not a mathematician, and unfortunately he is inexperienced with such techniques as linear programming, queueing theory, Monte Carlo method etc. Having a little experience in the area of airline Industrial Engineering, however, he hopes that he may be permitted to write of several potentially productive applications from the Operations Research point of view.

The broad approach to airline production planning and control has consisted of essentially three separate phases, simply stated as the development of the Operational Plan, the development of the Technical Plan and the integration of the two to produce a Production Plan. The first is done in cooperation with sales and traffic and flight operations, and has as its end result the flight schedules. The second is done in cooperation with engineering, maintenance and inspection, and results in the planned maintenance system and the progressive inspection schedule. The third is done in cooperation with maintenance and overhaul; the end results being the master work schedule, aircraft check schedules, component repair schedules and modification schedules, all of which have subsequent effect upon the stores and purchasing departments and, to some extent, affect the procedures of the accounting department.

What then are the main areas for decision making? The following considers each of the foregoing plans and suggests certain problem areas. An attempt will be made to relate them one to another in order to achieve an integration of the overall operating problem.

Operational Plan

Flight schedules

Major factors for consideration are route pattern, stage lengths, cruise speed, prevailing weather, interconnecting flights, time zones, load and revenue factors and crew time.

With present methods, this presents a complex problem, tedious of solution and necessitating compromises at all levels. The problem is made the more troublesome since, with several notable exceptions, the airlines of today do not appear to have progressed very far with the analytical or rational approach. During the war, and during the recent Korean conflict, the various military services developed Operations Research techniques for the optimum deployment of aircraft and ships. More recently, certain of the major airlines[4] have been able to fortify and simplify management decisions in a manner which is both exciting and encouraging to those of us who have yet to enter this field.

Undoubtedly the various phases of the problem must be attacked separately. Profitable areas of investigation will surely include the following.

Market research

It is patently evident that a primary purpose of any flight schedule is to carry revenue traffic "from point A to point B". The frequency out of, or into, a given point is largely dependent upon the traffic potential.

Two approaches are available. The first, assuming stable conditions, is the analysis of past experience to establish accurate load and revenue factors, also trends, by route and segment. The second, assuming a climate of expansion, requires the survey approach in new traffic areas, commodity as well as geographical.

Much has already been done in this field, both in our own and other industries. Perhaps what is required is to integrate this information more effectively and to make greater use of the experience of other industries nominally quite remote from our own.

Route analysis

Using existing formulae developed by the performance engineers, it is possible, through the use of Operations Research techniques and electronic computers, to optimize the conflicting factors of takeoff and landing characteristics of various en route airports, cruise control, altitude and wind, and to calculate operations data such as payload available, flight time, fuel burned and total direct operating costs.

Choice of equipment

With a known fleet size and flight schedule, making use of the direct operating costs developed above, using accepted methods for the determination of ground and indirect costs, and taking into consideration revenue and load factors, the profitability of a given aircraft over a given route pattern can be developed. In the case of new equipment determination, the same methods can be used to determine the relative merits of a number of potentially suitable aircraft.

Aircraft performance

All of the aircraft manufacturers and the airlines have developed their own formulae for the determination of aircraft performance. The logging of the pertinent performance data is a common practice. Using the statistical technique of variance analysis, each aircraft of a fleet can be compared one with another, and against a standard. Fuel costs, crew costs, crew and maintenance proficiency are among the products of such a study.

Flight planning

Several articles have recently appeared in the technical press describing the activity of the various meteorological services in the application of electronic data processing to the peculiar problems of meteorological forecasting. Lending impetus to this activity is the airlines' interest in the jet stream, and its effect upon high altitude flying with jet transports. It is reasonable to suppose that the logical conclusion of this activity is, with more accurate monitoring of route weather, the location of computers at major centres for the production of flight plans for individual departures. (The next and logical step, hastened perhaps by the pressing need to justify the high cost of electronic data processing machinery, is the integration of this information, for both incoming and outgoing aircraft, for the optimization of air traffic control.)

Crew routing

With modern trends, this area is assuming increasing importance from the direct operating cost point of view. The airline with an international route pattern is faced with the additional problem of the need for slip crews at outside bases, or alternatively the pre-emption of revenue seats; to say nothing of the effect of the particular policy on the pilot training requirements for aircraft time. Here is an area ripe for the application of the analytical approach, and should prove an excellent 'primer' application for Operations Research.

Operations Research summation

As mentioned previously, all of the foregoing have received the attention of the airlines these many years. Many have advanced far in their detailed techniques, and it might be said "there is nothing new here". If we are to make a case for Operations Research, the newness is to be found in considering them collectively and in the integration of market research, route analysis and equipment; to find the "key to . . . the fundamental mechanism of the operation", and in the determination of flight schedules having maximum effectiveness. The detailed study of the areas of aircraft performance, flight planning and crew routing will surely result in basic data having direct bearing on the "fundamental mechanism".

Technical Plan

Through the use of the periodicity list for aircraft maintenance, inspection and component overhaul items, and the use of the inspection or check schedule, the production planner is able to lay out and maintain a system to ensure the continuous airworthiness of an aircraft. This is commonly accomplished through the use of some form of progressive inspection or overhaul, covering the overhaul cycle of the aircraft. The emphasis at this stage of the plan is on the words "an" and "the" (aircraft). The next stage of the plan is the integration of the system on a fleet basis. With a given fleet size and a stable aircraft utilization it is a straightforward matter to finalize the Technical Plan for any given aircraft fleet, and to establish an adequately-spaced and regular cycle for the recurrence of *like* check increments.

Many will have had considerable experience with this exercise and will be fully aware of the compromise necessary to bring each aircraft of the fleet into the cycle. This is of increasing importance with the advent of turboprop and pure jet aircraft.

In view of the fact that it is difficult to define where the Technical Plan ends and the Production Plan begins, it is not proposed to go further with a discussion of the Technical Plan in this paper.

Production Plan

The criticism might be levelled, perhaps with some justification, that the previous section on the Operational Plan, dwells too long on the subject for a paper of this nature and size. In defence, it is submitted that the bedrock of any of the functions of production planning and control is accurate forecasts of aircraft utilization. This cannot be over-emphasized, and was dealt with at some length in a recent paper by the writer[3].

Aircraft routing and maintenance schedules

It will be appreciated that in addition to meeting the requirements of the flight schedule, the maintenance planner must also meet the requirements of the Technical Plan and ensure that the airworthiness requirements are complied with. Further, he has the additional responsibility of ensuring optimum utilization of both manpower and facilities. This latter is achieved by the development of work schedules which ensure a balanced workload.

Major factors for consideration are flight frequency (scheduled and training flights) and duration, check frequency and elapsed time, and the engine change schedule. Several additional factors can materially affect the problem, notably, non-scheduled charter flights, major mechanical delays and interior configuration changes.

Methods currently used by the writer's company are purely empirical; compromises are made at all stages and the resulting optimization (so called) is unduly time-consuming and inefficient. One attempt has been made, enlisting the aid of an outside concern, to reduce this problem to its basic fundamentals and to develop a mathematical model. The results of this exercise indicated too many uncontrolled variables; consequently we have had to "step back and re-group".

Possibly our approach was wrong; instead of the mathematical model we should perhaps be trying an operational or logical model using the Monte Carlo method[6] to study the probability of occurrence of the key variables and to simulate the system through the use of random numbers. In this approach, emphasis is placed on the use of statistical techniques in the analysis of existing historical data. Our own experiences in similar studies sound a warning here. All too often it will be found that much of the data required is either not available or not in usable form. It is interesting to note the experience of one of the leading airlines in this connection. "This experience will . . . be duplicated in many industries, and point up how little data is being gathered today which really measures operations, and enables management to manage, versus that required to satisfy legal, accounting, government agency, and staff needs."[6]

Material control

This is seen as a problem concerning rotable, repairable and consumable parts and material, and affecting to a considerable degree capital investment and operating expense.

Given aircraft utilization and a detailed progressive overhaul schedule, it is a simple matter to develop a schedule of arisings of rotables and repairables, and of airframe bits and pieces. From this can be developed realistic maintenance spares requirements, and the component repair and overhaul schedule. Given the latter, it is a relatively straightforward matter to determine the consumption of component overhaul bits and pieces.

Major problem areas are off-schedule removal of components and aircraft and component modification programmes. Considerable valuable work has been done in the first area by Hull[7] and others. However, the second area appears to defy rational solution.

Standards – labour and material

Reliable standards are the very life blood of any system of aircraft maintenance or component overhaul, and are essential in the forecasting of manpower and material requirements. As Operations Research techniques are developed, it will be found that standards are the 'aqua vitae' of many system simulations, particularly in the production control area. This lends emphasis to the need for development on two fronts: work measurement and simplification-methods analysis to determine 'the one best way', and the statistical analysis of historical data, assuming reliable source data.

The statistical approach is well established, and has been highly publicized during the past decade. Contributions are many, but notable among recent issues because of its combination of basic theory and practice is the work of Hieland & Richardson[8]. An excellent work on basic statistics is that of Moroney[9].

Further improvement in method through the medium of integration and the development of new statistical techniques will yield considerable gains.

Inventory control

It is possibly a high-handed approach, but it is the opinion of the writer that solution of the foregoing problems, particularly in the area of material control, will minimize the problems of inventory control which continue to plague the airlines. Considerable strides will also be made in attacking the problem of surplus analysis at source. However, it is contended that the latter is one area which will continue to present a problem – that of obsolescence due to modifications and to changes of aircraft type. The foreseeable solutions are purely empirical and consist largely of frequent stock review and decision through the use of some form of electronic data processing machinery.

Operations Research summation

Due to the impetus of World War II, the problems of production planning have received considerable attention and, therefore, it is common practice to seek solutions through the analytical approach. It is certain that much of the need for development of such Operations Research techniques as linear programming and queueing was due to the production planning needs of various industries.

Therefore it is contended that the area of production planning will prove a most fruitful field for the application of Operations Research.

The 'totality' concept

Referring to the Technical Plan and the Production Plan, it will be seen that for a given fleet size and utilization it is possible to predict with considerable accuracy, for a period during which operations can be controlled, the manpower and material requirements and, hence, total direct maintenance and material costs to support the operation.

Referring to the summation of the Operational Plan, it is conceivable that the information gained thereby can be integrated with the foregoing, again through the medium of fleet size and utilization, to create a simulation of the overall or total operation.

In the manner described herein, the basic pattern of the operation is determined, the key variables measured, their relationship determined, and the logical decision rules developed. If the model or simulation is then programmed on a computer, it can be used to test various ideas or plans by varying one item of the input to determine the effect on the various outputs which the model is programmed to produce.

In a matter of minutes, it will be possible to optimize the operation to test the effect of changes in policy, schedules, maintenance concept, facilities and manpower, in a manner which has tremendous potential – also, in a manner which provides an entirely new insight into the whole management field.

In this highly competitive industry of ours, we cannot afford not to investigate the potential of this new management tool. Obstacles will be experienced, both in problem solving and in overcoming human inertia, but surely there never was a greater incentive than the vista opened up by this new technique.

Accounting

Although primarily interested in such things as accounts receivable and payable, and in the balance sheet and the profit and loss statement, it is the writer's experience that our accountant friends are very alive to the need for operations control information. In the majority of cases, it is the accounting department which is the first among the airline departments to gain experience with electronic data processing machinery. The logical development of this experience is the establishment of an integrated data processing research group, whose function and activity closely parallel that of Industrial Engineering.

Quite often it will be found that the reports required by the various regulatory bodies, e.g. CAB and ATB, contain information which, presented in a somewhat different manner, can be of invaluable assistance to the operations researcher. Similarly, many accounting departments are running passenger and revenue statements which, if carried one or two steps further, could provide essential operations control information concerning revenue and load factors. The same could be said for the various space control procedures developed in recent years.

ELECTRONIC DATA PROCESSING

No discussion of this subject would be complete without mention of data processing and the role it must play. Electronic data processing machinery may be said to be essential to the Operations Research approach. With its use, the masses of data can be reduced more speedily and more accurately than by the routine use of head and hand. Further, with the integration of a computer, the process can be programmed so as to reduce optimization to a routine of submitting the mathematical or operational model to an almost infinite range of possibilities.

It is not within the scope of this paper to discuss the various types and pieces of electronic data processing machinery. This has been amply covered by the various manufacturers. Information is as close as their nearest representatives or the public library. It is considered sufficient to refer specifically to the technique of integration developed in recent years and to remind the reader that the various manufacturers are keenly interested in our problems and have given considerable thought to them[10, 11]. The same might be said of computers and their uses.

When contemplating the purchase or expanding the use of existing electronic data processing machinery, it will be profitable to carry in the forefront of the mind the experience of others. It is commonly accepted that an integrated data processing installation of any appreciable size can only be profitably employed when a volume of 30,000 bits of information per day is available. A computer installation worthy of the name (that is to say an installation which combines the computer with data processing machinery) has a price tag of $10,000 to $30,000 per month rental, or better. It will also be profitable to bear in mind that small computers are available, with a monthly rental as low as $500.

Maximum use of integrated data processing can only be achieved by the multi-use of source data. This requires a source document acceptable to all users and uses. The establishment of acceptable source data is a major problem and too often it will be found that necessary compromises weaken considerably the end use information available to individual departments.

Finally it has been the experience of a number of users that it is not the use of integrated data processing techniques which saves the money, but rather the streamlining and improvement of procedures which precede the application and lead up to the programmes developed for the "mechanical brain". It has become a platitude to say that the process is no better than the information fed into it.

OPERATIONS RESEARCH ORGANIZATION AND ADMINISTRATION

Operations Research should report to the Chief Executive Officer of the organization which it serves. Ideally, if a company embarks on such a programme, it should report directly to the President, or Executive Vice-President. However, in practice it has been found workable to have the function reporting to the Vice-President, Operations. One case can be cited where the function reports to the Vice-President, Industrial Engineering.

The team concept is the commonly accepted practice; a team with diversified research experience. Such a team might comprise the following:

Mathematician – Preferably a Ph.D. in applied mathematics or physics. Practical experience in industry and the application of Operations Research techniques to industrial problems are essential.

Industrial Engineer – Preferably a university graduate in engineering with practical experience in the application of such Industrial Engineering techniques as work simplification, sampling etc.

Economist – Preferably a university graduate in economics or commerce with industrial experience at both operating and corporate levels.

Group Head – Preferably a senior officer of the organization which the function will serve. Although specialized knowledge is not required, the ability to determine the *application* of specialized techniques is essential. The translation of the scientific work of the group into terms understandable by top management and lower levels will be of prime concern.

Because of the high qualifications required, such a service as outlined above will not come cheaply. Total annual salary for such a group will be close to $50,000. Although appreciable, this figure pales beside the savings in reduced fleet size with individual aircraft costing $5,000,000 in the future. Additionally, it should be weighed in the balance against a possible wrong decision as to future aircraft type.

CONCLUSION

Upon re-reading the paper, the writer was aware of its limitations. It is entirely too long on problems and too short on solutions. However, if it does no more than indicate a possible trend, and channel the thoughts of the interested reader, it may thereby be said to have served a useful purpose.

One thing would appear certain – there must be development, in individual areas if not collectively. It behoves the industrial engineer to prepare himself for this development. Senior management is in need of an interpreter in the field of Operations Research, and it would appear natural that it should be the industrial engineer who will be expected to provide such a service.

The possibility of simulating and testing ideas on operating conditions is extremely exciting. The industrial engineer needs to develop techniques which permit the testing of his ideas elsewhere than on the production floor. It is not necessary to wait for an Operations Research group to be set up. All that is needed is to take up the challenge of this new concept, to take existing procedures and systems and to develop them to the state where they can be simulated. You will find willy-nilly that you are researching in the operations field. The totality concept need not be achieved overnight in one fell swoop. Indeed it will be found in practice that Operations Research must tackle each problem separately, but like 'the ripples on the pond' the researcher will find the ever-widening circles taking him into other areas, until the end result is the goal achieved – *Totality!*

ACKNOWLEDGMENT

The writer wishes to extend his gratitude to the many individuals who have lent a sympathetic ear in many a discussion of these problems, particularly to those colleagues and associates who have all assisted in developing the writer's understanding and appreciation of the subject. Special thanks are due to United Airlines Inc. for providing copies of several papers prepared by members of their Industrial Engineering group. Some of these are included in the list of References.

The help of Professor H. Wilkinson, University of British Columbia, and of Mr. H. J. Heinrich, Trans-Canada Air Lines, in their critical review of the paper is very gratefully acknowledged.

The writer wishes also to thank his Company, Canadian Pacific Air Lines, Ltd., for the opportunity to present these views.

The views expressed in this paper are those of the writer, and do not necessarily reflect the policy of the Company with which he is employed.

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C.A.I. LOG

SECRETARY'S LETTER

ANGLO-AMERICAN CONFERENCE

During the past month so much of my time has been taken by the Anglo-American Conference, that it is difficult to know what to tell about it and what to leave out.

New York

However it is easy enough to know where to begin. Unfortunately our President was unable to get to New York except for the Conference Dinner and, since no other members of our Council were present, it was my privilege to represent the CAI, as a society, on the one or two occasions when such representation was required. I cannot speak too highly of the reception I received and, on behalf of the Institute, I must express our sincerest thanks. Both British and American delegates went out of their way to tell me how glad they were that the CAI was participating in the Conference and, when one realizes how closely this series of international meetings has been built around the Anglo-American theme, this was a welcome indeed.

I attended the last Conference, in England in 1957; that one was run, of course, by the RAeS. It was interesting to compare their methods with those used on this occasion by the IAS and I hope that, in the running of our own meetings, I can learn something from both. Mrs. Ross came to New York too, and the IAS staff, up to their eyes in their own problems, still found time to show us some of the tricks of the trade. In our IAS/CAI Meetings they have already taught us nearly all we know, but it was most instructive to have this intimate view of the IAS staff in action themselves.

One of the most striking developments was the British method of preparing their slides. After the last Conference there was a certain amount of criticism of slides used by some of the speakers and the British evidently took it to heart. So did I; I asked both our speakers to ensure that their slides were good; and they were, with the ordinary black lines on a white background. But the British slides were all to a standard pattern, having brilliantly luminous coloured lines, generally orange or green, on a black background. I understand that they were all prepared by Bristol Aircraft. Though good slides are not necessarily the making of a lecture, bad slides can certainly ruin it.

Toronto

The part of the Conference that took place in Toronto was in some senses a disappointment. The programmes of visits went well enough – which was a miracle, when one considers that we were faced with the job of coordinating two independently arranged programmes, our own and the UTIA Symposium. But the attendance was poor. From the American point of view we were handicapped by our place at the end of a fortnight's Conference and those who were in New York could scarcely afford the time to come on to Toronto later; realizing this, we were all the more happy to welcome Mr. Littlewood, Dr. Sharp, Mr. Johnston, Mr. Dexter and Mr. Harris, who managed to be with us at great personal inconvenience. We can only attribute the poor showing from the Canadian side to the facts that Toronto is still groggy from the Arrow catastrophe and that the programme, consisting entirely of visits, was not sufficiently meaty to justify much attendance from remoter Branches. I think that the British delegation – there were about fifty of them – were generous enough to understand the situation; at any rate they were the most gracious guests.

GOLDEN ANNIVERSARY

The National Co-ordinating Council for the Golden Anniversary of Flight in Canada held its final meeting in Montreal on the 27th October, during the Annual General Meeting of the AITA. I think it did a tolerably good job during the year; at least, I shudder to think of the clashes between the programmes of the member organizations if the Council had not existed – notably between ourselves and the RCAF in our celebrations on the 23rd February. As representative of the CAI I had the honour to be Treasurer of the National Co-ordinating Council and our members will be pleased to hear that I did a job worthy of them. We ended up in the black!

AMENDMENT OF THE BYLAWS

During the current month members will be asked to vote on some amendments to the Bylaws and the following is an explanation of their significance and the reasons behind them. The amendments can be grouped under four main headings, of which the second, concerning the Council, is much the most important; in fact, the others introduce no changes of any consequence and are being proposed by the Council to bring the Bylaws into line with their long-established interpretation; the fourth group amounts to little more than improvements in the drafting of various clauses. Members will be asked to vote on each group, as a whole.

Group (i) The Object of the Institute

The amendment adds a sentence to the existing definition of the Object of the Institute to remove any doubt of the Institute's interest in all forms of flight including space travel. This view was expressed in the Editorial "Off the Ground" in the April, 1958, issue of the Journal, but it ought to be laid down in the Bylaws.

Group (ii) The Council

For the past eighteen months, the Council has been studying its own constitution and is now suggesting some significant changes. When the Institute was formed, by the amalgamation of existing organizations in Toronto, Montreal and Ottawa, each being replaced by a Branch of the new Institute, it was natural that each Branch should claim representation on the Council and the arrangement whereby two seats should be assigned to each was the obvious solution. A two year term of office was established and each Branch was required to elect one member of the Council every year, to give an overlap. Provision was also made for the bigger Branches to be represented by more members on the Council than the smaller ones; the original formula for this feature was amended slightly (but not in principle) in 1956 to provide for 3 members of the Council for Branches with more than 400 members and 4 members of the Council for Branches with over 600 members.

This scheme for the constitution of the Council has worked fairly well but, as the Branches have increased in number and size, the Council has grown more and more unwieldy and it has become increasingly difficult to hold Council meetings with a quorum. In consequence the administration and management of the Institute has tended to become centred in the three-man Executive Committee and, though the Council is kept fully and promptly informed of the Executive Committee's decisions, it often has little opportunity to influence them; this is rule by "cabinet" rather than by "parliament" and is an unhealthy state of affairs. There are other disadvantages to the existing formula — for example, the addition of two new members to an already large Council with the formation of each new Branch is inclined to temper the encouragement of the formation of Branches — but it is not necessary to refer to all the points that have arisen during the Council's exhaustive discussions of the matter and consultations with the Branch Executive Committees. The new proposal now amounts to this:

(a) The term of office of members of the Council should be 3 years (instead of 2).

(b) Branch elections should be so arranged, over a 3-year period, that the Council would consist of 1 member (instead of 2) for each Branch having up to 400 members, 2 members (instead of 3) for each Branch having 401 to 600 members, and 3 members (instead of 4) for each Branch having over 600 members. Applied to existing conditions, this formula would produce a Council of 13 (instead of 22) and materially decrease its rate of growth with any increase in the number and size of Branches.

(c) A quorum should be 60% of the Council (instead of one member from every Branch — a terribly restrictive requirement in the light of our geography).

(d) The President and Vice-President for the coming year should be elected two months before they are due to take office (instead of at the Annual General Meeting at which they take over from their predecessors).

(e) Several relatively minor provisions, about the filling of vacancies and the steps taken when new Branches are formed, which do not greatly alter the existing procedures.

Group (iii) Membership and Dues

For the past two years the Council has delegated the power of admission to the Admissions Committee, with provision for appeal to the Council. The Regulations are being amended to confirm this arrangement and reference to "admission by the Council" is being deleted from the Bylaws.

In addition the clauses defining the qualifications for the grades of Member and Technical Member are being simplified and clarified, and the definition of an Associate is being broadened to include people who have been engaged in aeronautical work but are not necessarily so engaged at the time of admission.

The clause referring to entrance fees, which used to imply that an entrance fee was payable on every regrading, is being corrected in this respect.

Group (iv) Miscellaneous

This Group consists of amendments intended to improve drafting and introduce some consistency in the use of words but, in effect, to change nothing in the meaning and intent of the clauses concerned.

PROCEDURE

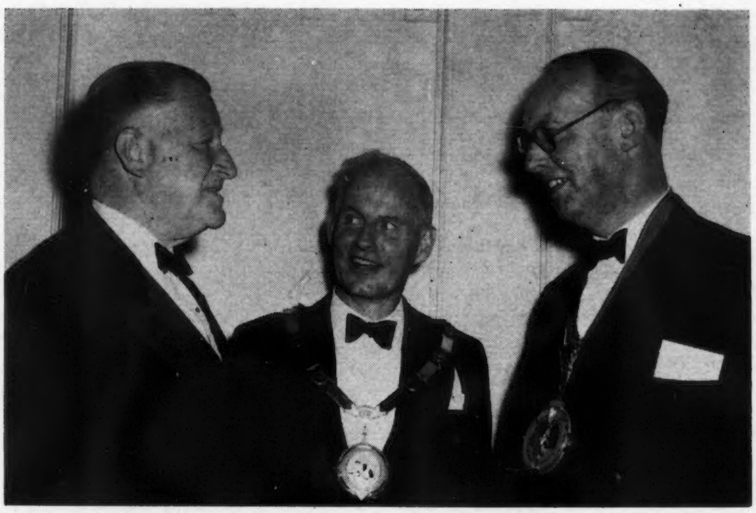
The amendments described above were approved by the Council at its meeting of the 17th October, 1959. They are being submitted to the membership and if adopted by a two-thirds majority will be placed before the Secretary of State for ratification.

If Group (ii) is accepted by the membership and if it is possible to complete the procedure before the next Branch elections, a scheme of transition, already prepared by the Council, will be introduced; it will bring the new constitution of the Council into full effect by the year 1963-64.

ANGLO-AMERICAN CONFERENCE

NEW YORK

SOME 35 Canadians, most of them members of the CAI and at least one from as far away as Edmonton, attended the first part of the Seventh Anglo-American Conference, which took place in the Astor Hotel, New York, from the 5th to the 7th October. Total registration was 506. The two Canadian speakers, Mr. R. D. Hiscocks and Dr. G. V. Bull, contributed most ably to the programme of twenty-one technical papers.



The three Presidents: (l to r) Mr. W. Littlewood, President IAS, Dr. D. C. MacPhail, President CAI, and Mr. P. G. Masefield, President RAeS

This first participation in the Conference by the CAI received a very warm and generous welcome from both the RAeS and the IAS delegations and, though the part played by the Canadians was a relatively small one, it was accorded rather more than its fair share of attention. As an example it is worth quoting the exchange of telegrams between Mr. P. G. Masefield, President of the RAeS, and Her Majesty the Queen, which Mr. Masefield read at the opening ceremony.

Mr. Masefield's message was as follows:

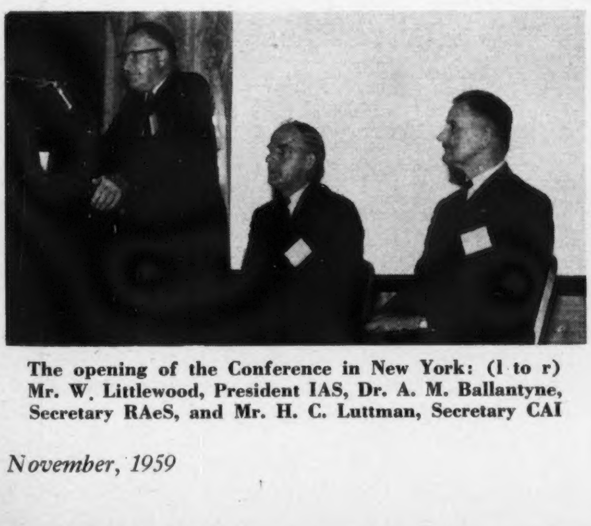
"Before leaving for the United States, the President, Council and Members of the Royal Aeronautical Society, with their humble duty, beg to submit to Your Majesty, as Patron of the Royal Aeronautical Society, their loyal greetings on the occasion of the Seventh Anglo-American Aeronautical Conference in New York with the Institute of the Aeronautical Sciences of the United States. For the first time since the inception of these conferences in 1947, the British Society and American Institute are joined by the newly formed Canadian Aeronautical Institute. In a year in which Your Majesty has undertaken an historic tour of Canada, which has included so many miles by air, it is particularly appropriate that the Canadian Institute should join this important conference on the scientific and engineering problems of the future in the air.

"In sending Your Majesty our loyal greetings, we trust that our endeavours in advancing the cause of aeronautics throughout the world will serve to draw ever closer together the English-speaking nations of the world, in the destiny of whom we know Your Majesty is so deeply interested."

To which the Rt. Hon. Sir Michael Adeane, Private Secretary to Her Majesty, had replied:

"The Queen as patron of the Royal Aeronautical Society is most grateful to you and to the Council and Members for your kind and loyal message sent on the occasion of the Seventh Anglo-American Aeronautical Conference. Her Majesty sends her best wishes for the success of your deliberations with the Institute of the Aeronautical Sciences of the United States and the Canadian Aeronautical Institute."

The concluding event was the Conference Dinner on the 7th October, at which the Elmer A. Sperry Award for



The opening of the Conference in New York: (l to r) Mr. W. Littlewood, President IAS, Dr. A. M. Ballantyne, Secretary RAeS, and Mr. H. C. Luttman, Secretary CAI

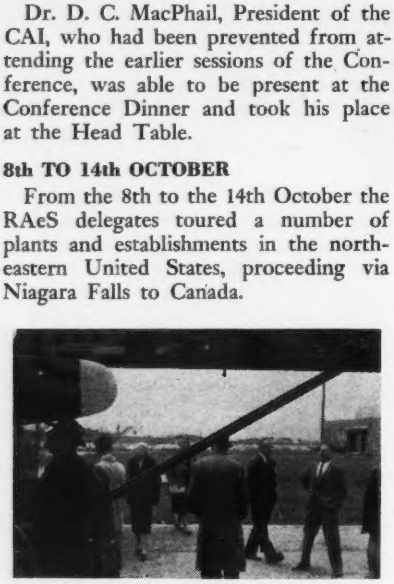
Delegates to the Conference in the corridors of the Astor Hotel

a distinguished and demonstrated contribution to transportation by land, sea or air (it is sponsored jointly by the ASME, the AIEE, the SAE and the SNAME) was awarded to Sir Geoffrey de Havilland, Mr. Charles C. Walker, Major Frank B. Halford (posthumously) and their co-workers at the De Havilland Aircraft Company, for the Comet. Unfortunately both Sir Geoffrey and Mr. Walker were unable to be present, due to ill health.

Dr. D. C. MacPhail, President of the CAI, who had been prevented from attending the earlier sessions of the Conference, was able to be present at the Conference Dinner and took his place at the Head Table.

8th TO 14th OCTOBER

From the 8th to the 14th October the RAeS delegates toured a number of plants and establishments in the north-eastern United States, proceeding via Niagara Falls to Canada.

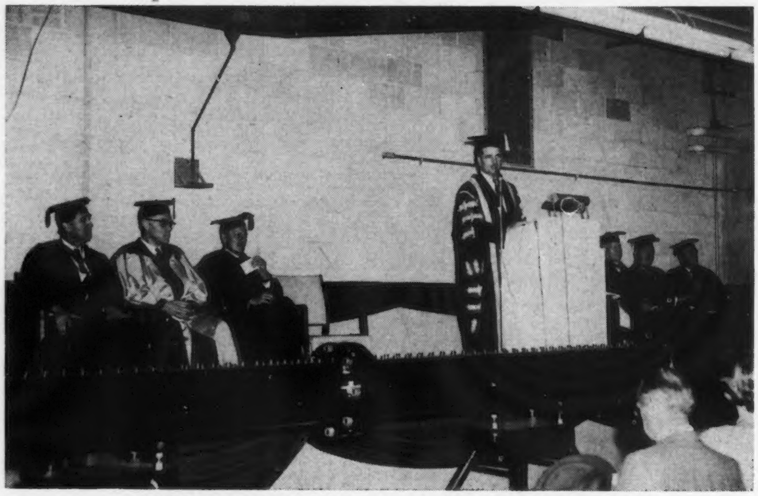


Examining the DHC Caribou

TORONTO

The visitors arrived in Toronto on the 14th October. On the following morning they visited the Downsview plant of the De Havilland Aircraft of Canada, where, after a general briefing on the history of the Company and the technical development of the Chipmunk, Beaver, Otter and Caribou, they examined a static display of these aircraft and witnessed a flying demonstration of the Caribou and the experimental STOL Otter. The visit concluded with an excellent luncheon; the De Havilland hospitality was very much appreciated, for it had been a little chilly out there on the tarmac watching the flying.

After lunch the party went to the Defence Research Medical Laboratories on the other side of the aerodrome. The programme started with a series of talks by members of the staff, outlining their particular fields of work such as Human Factors, Vestibuler Physiology and Environmental Physiology, and afterwards the party split up into groups to visit the various laboratories including the Decompression Chamber and the Human Centrifuge at the Institute of Aviation Medicine. This visit to the DRML was one of the highlights of the entire



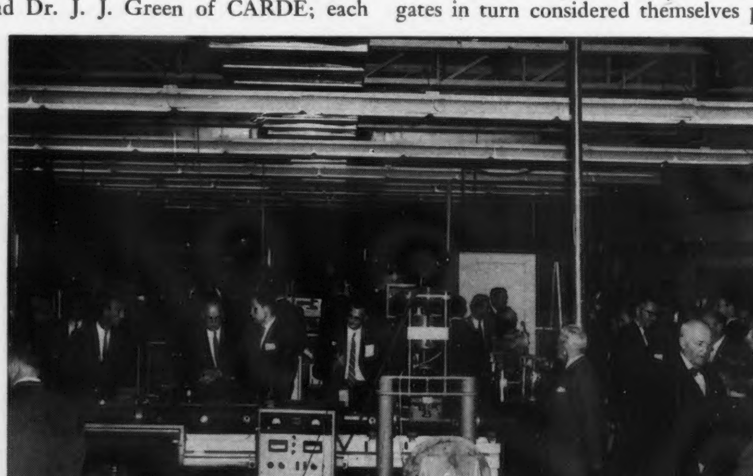
UTIA; introductory remarks by Dr. Claude Bissell

programme; the series of short talks was very well done and aroused a great deal of interest and discussion.

The Dinner, which will be reported later, took place that evening.

On the 16th October, the last day of the Conference, some of the RAeS delegates, by special invitation, attended the closing session of the three-day Decennial Symposium at the University of Toronto, Institute of Aerophysics; the others followed later in the morning and joined the group for luncheon at the "Four Winds", a restaurant near the new UTIA laboratories in the northern outskirts of Toronto. The luncheon concluded with a Panel discussion on "Canada's Technical Role in the Space Age" under the chairmanship of Dr. G. S. Field. The panel comprised of Dr. J. C. Evvard of the NASA, Dr. D. C. Rose of the NRC, Dr. H. S. Ribner of UTIA, Dr. P. A. Lapp of De Havilland and Dr. J. J. Green of CARDE; each read a brief paper on different aspects of the subject and the session ended with a few questions from the floor. The general conclusion seemed to be that Canada's technical role in the Space Age lay in instrumentation and the study of space near the earth.

The final feature of the programme was the official opening of the new UTIA laboratories. Delegates to the Conference and those attending the Decennial Symposium gathered in the main laboratory where they were addressed first by Dr. C. T. Bissell, President of the University, then by Dr. A. H. Zimmerman, Chairman DRB, who declared the laboratories open with an impressive volley of shock tubes, and finally by Dr. G. N. Patterson, Director of the UTIA and Past-President of the CAI. While Dr. Bissell and Dr. Patterson both welcomed the Anglo-American Conference to this University ceremony, the delegates in turn considered themselves pri-



Tour of the UTIA laboratory after the opening

vileged to be present at the birth of this significant and important contribution to Canadian aeronautical research.

THE DINNER

The Dinner held in the Park Plaza, Toronto, on the evening of the 15th October, was the last formal meeting of the Conference. Unfortunately the attendance was only 131; it should have been better and those who stayed away missed a most enjoyable evening.

Dr. MacPhail was in the chair and, in welcoming the RAeS and IAS visitors to this first gathering of the three societies on Canadian soil, he said that he had notified the Institute's Patron, the Prince Philip, of this important event; he read the following exchange of cables:

"To His Royal Highness The Prince Philip:
The Canadian Aeronautical Institute is participating this year for the first time in the Anglo-American Conference held biennially by the Royal Aeronautical Society and the Institute of the Aeronautical Sciences. The Conference begins in New York and will conclude with a two day visit to Canada including a dinner in Toronto on October 15th. I am sure that you, Sir, as our Patron, will wish to join your Institute in welcoming our senior and distinguished sister societies to Canada.
D. C. MacPhail, President"

"To Dr. D. C. MacPhail:
As Patron of the Canadian Aeronautical Institute I am very pleased to welcome the Royal Aeronautical Society and the Institute of the Aeronautical Sciences visiting Canada. I wish the Conference every success and send all those dining together in Toronto my best wishes.
Philip Patron"

His Royal Highness' gracious greetings were very warmly applauded.

After a reference to the Fiftieth Anniversary of Flight in Canada and the ceremonies in Montreal on the 23rd February, at which both the RAeS and the IAS had been represented, the President reviewed the structure and development of the CAI; he thanked both the British and American "parents" for their most generous help and advice during its formative years. He then proposed a toast to the Royal Aeronautical Society.

Mr. Masefield replied on behalf of the Society. He began his entertaining and witty address with a reference to the banners of the three groups hung behind the Head Table and, metaphorically, tore all three of them to shreds. He expressed his pleasure at the CAI's entry into the Anglo-American Conference and at Mr. Luttman's presence officially representing the CAI at the opening ceremonies in New York. Since this Dinner was the last occasion on which the delegates would be gathered together, Mr. Masefield took the opportunity to thank the IAS for the warmth of their welcome and their great hospitality to the RAeS delegates in New York and later on their tour of American plants and facilities; and he paid a special tribute to Mr. William Littlewood, President of the IAS, who had spared no time or effort in looking after them and who had endeared himself to them all. He also thanked the RAeS staff for their hard work in all the preliminary arrangements for the Conference.

View of the Empress Room in the Park Plaza during the Dinner

Mr. Masefield spoke highly of the solid progress which was being made by Canadian aviation, in spite of occasional "hiccups", and admitted that this malady seemed to be afflicting aviation in general. But he warned the societies not to be thrown off balance by the present attractions of the problems of space travel; there were many problems of atmospheric flight yet to be solved and he felt it important that the three societies should keep on working together to their solution.

He concluded by proposing a toast to the CAI.

Dr. MacPhail thanked Mr. Masefield most sincerely for his kind words and good wishes, and then referred to the IAS and the support and guidance that they had given to the CAI in the series of annual IAS/CAI Joint Meetings and whenever their advice had been sought. He proposed a toast to the Institute of the Aeronautical Sciences.

Mr. Littlewood replied to the toast and expressed his appreciation of the remarks made by the other two Presidents. While in New York he had given an undertaking to Mrs. Ross and Mr. Luttman, that he would tell an Indian story at this Dinner if the CAI would provide an Indian. The best that the CAI could do was a feather worn by Mrs. Ross, sitting just in front of the Head Table, and a peace pipe laid at Mr. Littlewood's place. He did better; he puffed the peace pipe (unlit and unlightable alas!) and told his story (which was unfortunately too long to repeat here).

On the more serious side Mr. Littlewood denied that there was, in fact, a general depression in aviation but rather a need for reorientation and reappraisal of objectives. Enlarging on Mr. Masefield's reference to the unsolved problems, he listed the ground handling of aircraft, the takeoff characteristics of jet transports and the need for greater control at takeoff, the development of high lift coefficients, noise, economy, safety, collision prevention and air traffic control, airport to city transportation and the whole field of cargo and freight handling. He also urged prime contractors to diversify their activities into fields which had been allowed to pass to specialist sub-contractors and to regain control of the whole business of building aircraft. He called for more originality and questioned the wisdom of the trend towards elaborate and expensive research, citing the De Havilland Aircraft of Canada, which had been visited that morning, as an example of what can be done with a little straightforward, practical engineering.

The proceedings were wound up by Dr. J. J. Green, who was called upon by the Chairman to move a vote of thanks to Mr. Masefield and Mr. Littlewood. Dr. Green, who had been closely associated with the formation of the CAI, and was in fact its first President, pointed out that the RAeS and IAS had been almost entirely responsible for the birth and growth of the Canadian Institute and that, if they now had any complaints about it, they had only themselves to blame!

To judge from the reaction nobody had many complaints or was in any mood of self-recrimination. For its part the CAI looks forward to future family gatherings of this sort.

BRANCHES

SURVEY OF THE BRANCHES

STARTING with this issue of the Journal, the Institute will run a series of descriptive accounts of all the Branches. The purpose of this series is to provide an overall picture of the work the Branches are doing, of the make-up, principal interests, problems and particular difficulties of each, and the part it can play in furthering the objects of the Institute.

Calgary

By J. D. Zmurchyk
Chairman

In retrospect of the efficacious few who have observed, participated and experienced the growth and operation of the Calgary Branch during the 1958-59 year I can only say that we can look forward in enjoying another successful year. Going into the second year I know that the officers are more than capable to anticipate the technical demands by the membership from the fast expanding aviation world.

The scope and essence of Branch programmes should be somewhat intrinsic yet flexible throughout the season to meet the interest of all members.

The factors to be borne in mind regarding this point will always hinge on the environment of the Branch area. Therefore, this can be remedied by the selection of technical subjects to the general satisfaction of everyone.

With the advent of space development and research many members are casting their interest in this direction. Programme Committees must now become interjacent to any technical potential in this field.

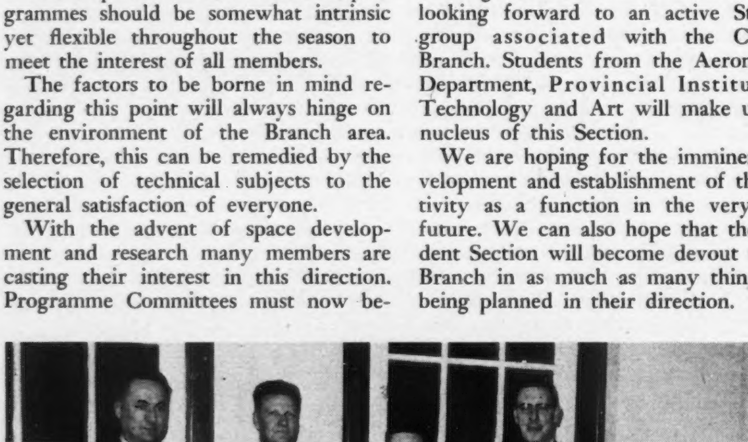
Though Calgary may be isolated somewhat from the aviation industry in the main, we are finding a healthy indication towards all fields, though this handicap may exist.

It would appear that general interest should lie in the maintenance and operations category. However, it is felt that interest has been accepted beyond and into many others, such as development, research, space and astronautics, manufacturing, etc. One could predict that varied technical papers from far afield will always be accepted with no predilection.

With this in mind one can clearly visualize the ultimate which is attained and brings forth the ideals and principles of the Branch and Institute.

Members in this area are mainly associated with aircraft maintenance, operations and overhaul. Where manufacturing, research and development is non-existent, then we lack this kind of member participation at our Branch meetings. I should mention that we are looking forward to an active Student group associated with the Calgary Branch. Students from the Aeronautics Department, Provincial Institute of Technology and Art will make up the nucleus of this Section.

We are hoping for the imminent development and establishment of this activity as a function in the very near future. We can also hope that the Student Section will become devout to the Branch in as much as many things are being planned in their direction.



Calgary Branch Executive Committee
Standing: (l to r) Mr. W. R. Burge, Mr. G. Fryer, Mr. H. McKenzie and Mr. W. E. Jamison. Sitting: (l to r) S/L M. R. Barrett, Mr. H. E. Hampshire, Mr. J. D. Zmurchyk and Mr. G. H. Ryning

Additional interests should be found within the RCAF. Many developments that take place there should be the concern and demands of each member. In turn it is the duty of the Programme Committee, when possible, to avail themselves of any technical charge from this source.

Our Programme Committee is looking forward in obtaining speakers again who so ably carry a great technical interest to the membership. I would like to mention with direction to the other western Branches, that a correlative view in mind certainly helps in obtaining any distant speakers. This makes it worthwhile in as much as a very good tour can be achieved or accommodating for those concerned.

The majority of Branch gatherings take the form of a dinner meeting. All meetings are generally held at the Al San Club, RCAF Lincoln Park or the Provincial Institute of Technology and Art.

Many ribbons should be cut when the newly formed entertainment group becomes geared in its responsibility for this year's social functions.

All in all the Branch, we believe, is slowly becoming a most worthwhile endeavour to its members.

Toronto

By Dr. J. H. T. Wade
Chairman

The Toronto Branch of the CAI had its origin as a Section of the Institute of the Aeronautical Sciences. The IAS Section in Toronto was formed in 1947 and in 1954 the Section members voted to join with Ottawa and Montreal groups to form a nucleus of the Canadian Aeronautical Institute.

In this area we have a complete cross section of the Canadian aeronautical industry and technology and, if we have any problem at all, it is due in part to this diversity of interests. In a single year's program for instance it is almost impossible to provide for all the interests of the splinter groups. We have attempted in the past to provide programs of a semi-technical nature in order to reach as large an audience as possible and to balance these with technical programs in which a rather deep penetration is made at one particular point in the field. For a number of years now we have also sponsored a field trip in the form of a plant tour. These tours,

held in the evening, are well attended and give one the opportunity of seeing the facilities offered by the aircraft and allied industries.

Each season the Toronto Branch holds ten meetings, including one field trip and a dinner meeting to conclude the season. The meetings are held in the De Havilland Cafeteria which has been made available to the CAI for the fourth year in succession. Seating 425 and completely equipped for lecture purposes, the Cafeteria is ideally situated in the north-centre of the city and has more than ample parking facilities. The bar and buffet are operated on a non-profit basis, merely covering the fees of the barman, the buffet, licence and supplies.

It is, I think, worth noting that the meetings were formerly held in one of the lecture rooms at the University of Toronto, and the average attendance was possibly around 50 people. Parking was always a problem near the University and the heavy city traffic for members living in the suburbs was instrumental in keeping the average attendance low.

Toronto Branch Executive Committee
Standing: (l to r) Mr. G. F. W. McCaffrey, Mr. K. Jay, Mr. N. Walsh, Mr. C. F. deJersey and Mr. K. Kinsman. Sitting: (l to r) Mr. E. J. Lynch, Mr. C. H. Bottoms, Dr. J. H. T. Wade and Mr. W. H. Jackson
Missing: Dr. G. N. Patterson and Mr. J. P. Uffen

At one time the intention of the Branch was to hold the meetings on the second Wednesday of each month. However, in the last three years the Branch policy has been more fluid and the meetings are now held as near the middle of the month as possible – in many instances at the convenience of the speaker. Wednesday night is extremely popular with a number of organizations in the Toronto area. Some of the most popular extension courses at the University fall on Wednesday evening. It was also found that a number of wives wanted to attend night school on Wednesday and the CAI meetings are now held on Tuesday or Thursday, at which time a greater percentage of the members are free.

The complete program of the meetings is generally laid out in a skeleton form at the first Executive meeting, usually held in June before the summer holiday season. To this meeting a number of senior members of the Branch are invited and tentative program items are discussed with an overall program emerging. The Vice-Chairman of the Branch is usually designated as Program Chairman but considerable assistance is requested and received from all the members, particularly during the planning stages since the year's programs are probably the most important function of the Branch Executive.

As to the programs in general, we have in the past few years not followed a definite theme throughout the year, since by experience it was found that the theme was difficult to maintain and still provide interest for the fringe groups. Because of our varied interests the programs are now of a heterogeneous nature.

We are fortunate in having in the area the University of Toronto, Institute of Aerophysics. For years the Institute has maintained a seminar program for which outstanding guest lecturers in the fields of Aerophysics, Aeronautics and Space are brought to the Institute for a speaking engagement. Each year one of these speakers has been made available to the CAI at no cost to the Branch. This provides a meeting in which the subject is treated on a high technical plane for which the members in the Toronto Branch are most appreciative.

I think one of the outstanding contributions of the Toronto Branch is its support and recognition of technical education in the area. Several years ago, in co-operation with the Department of Aeronautical Engineering at the University of Toronto, an annual students thesis competition was inaugurated. In this continuing competition an award is given to the best thesis presentation of an undergraduate student in aeronautical engineering at U of T. Last year the January meeting was devoted to this competition, at which the three best papers were given, judged initially by the U of T advisory committee. Cash awards are presented to the three finalists, based on their presentation as judged by three senior members of the CAI. Last year the Executive Committee decided to enlarge the educational program in the Branch and separate awards were made to the outstanding students at both Ryerson Institute of Technology and Central Technical School in the field of Aeronautical Engineering. The awards will in the future also include the Hamilton Institute of Technology which has just started operation.

It has also been the practice in the last few years to ask the various Specialists Section of the CAI to provide a speaker for the monthly meetings. Last year for instance both the Propulsion and Astronautics Sections provided a guest speaker of a very high calibre and are planning to follow the same procedure this year. The Branch was also able last year to exchange speakers with the Canadian Astronautical Society and this provided an additional lecture in Astronautics which was very well attended. This type of mutual aid program is of considerable importance to the Branch when the speakers are chosen with care, and the meeting dates of the two societies do not conflict.

As far as the balance between technical and social events are concerned, I am able to report that the Toronto Branch, to the best of my knowledge, has never held a strictly social evening. The ten or so meetings held each year are completely technical, with only the annual dinner meeting showing any deviation from the routine. Even this meeting has a technical flavour with an after-dinner speaker being the general rule.

At the time of changing over from the IAS to the CAI the membership in the Toronto area numbered some 144 persons. Some indication of its growth during one of the boom periods of Can-

adian aviation can be seen from the fact that just a year ago there were approximately 700 members in the Toronto Branch, with the average meeting attendance around 200 people — members and guests.

With the cancellation last February of the Arrow-Iroquois contract, many of the Toronto members left the area and still others changed from the aeronautical field so that today it is estimated that the Branch constitutes some 400 members.

NEWS

Montreal

Reported by W. H. S. Bird

September Meeting

A meeting of the Branch was held on the 18th September in the Airlines Restaurant. The Branch Chairman, Mr. R. F. O. Smith, conducted the meeting and welcomed 113 members and 27 guests.

As this was the first meeting of the season, the Chairman introduced the new Executive, Councillors and Committee Chairmen for the year. After the introductions he read extracts from Mr. H. C. Luttman's letter asking for papers which might be suitable for publication in the Journal.

Following the dinner, Mr. J. W. J. Truran introduced the two speakers of the evening from Canadair Limited, Mr. T. A. Harvie, Assistant Chief Engineer, Administration, and Mr. C. E. B. McConachie, Manager, Sales Engineering. Mr. Harvie, with the aid of slides, outlined many of the innovations and interesting design problems connected with a swing-tail, 205,000 lb aircraft. The variety of loads and the number of problems involved in loading a cabin 98 ft in length were illustrated and several passenger versions, where up to 172 economy-class passengers plus normal baggage and cargo could be carried, were also shown.

Mr. McConachie, also assisted by slides, demonstrated the outstanding versatility and economic savings possible. For example, based on the 1955 ATA method, it was estimated that over stage lengths of 1,000 miles, domestic cargo could be carried at a direct operating cost of less than 5c per ton-mile, at a stage length of 2,500 miles the direct operating cost would be about 4½c per ton-mile. A high density passenger version with a total of 172 passengers could carry a passenger from Montreal to Vancouver at a price considerably less than the corresponding rail coach fare.

At the conclusion of Mr. McConachie's address, the speakers were thanked by Mr. A. E. Ades for a very interesting talk.

October Meeting

The Branch held its monthly meeting on October 22 at the Airlines Restaurant, International Aviation Building, Montreal. The Chairman, Mr. R. F. O. Smith, welcomed 121 members and 12 guests to the meeting.

Mr. A. M. Scott introduced the speaker, General Claude Tessier, North American Representative for Sud Aviation, who talked on "The Caravelle Picture" aided by slides and a motion picture.

General Tessier reviewed the history of the Caravelle and outlined several of the more salient features including the rear engine arrangement which is now appearing on several new aircraft. Mention was made of the pressure testing tank where a complete test aircraft has gone through 22,000 simulated flights. Some time was spent covering the twin-engine versus four-engine aspect and the absence of cabin noise. He felt the Caravelle configuration of two aft mounted Avons, 50 ton gross weight, 70 plus passengers and a cruising speed of 505 mph for a range of 1,000-1,200 miles, made an ideal short-medium range transport of which 55 had been ordered with 19 on option. He was disappointed that so far they had been unable to crack the North American market. He also mentioned the economic and political difficulties involved and compared the task with trying to sell California wine in Burgundy. With Varig Airlines (Brazil) purchasing two, he hoped that as the Caravelle appeared at New York on its regular flights more American operators would become interested.

The talk was followed by a film of the Caravelle showing manufacturing processes, test flying, service flying, passenger amenities and handling, etc. Although obviously produced for general sales work rather than the engineer, it was one of the finest films of its type the writer has seen.

Mr. Scott sparked the question period by asking how the Caravelle met the SR422 requirements. Gen. Tessier replied that the design conformed to US CAR as well as French requirements and on normal runways needed no thrust reversers, etc. However because of possible runway conditions, SAS were having tail-chutes in their version, so was Air France, and to suit the thoughts of American operators they were developing a thrust reverser system based on that used on the Hawker Hunter.

Concerning a query on noise, it was pointed out that the Caravelle was the first jet aircraft to be given a clean bill by the Port of New York Authority as meeting their requirements. Noise levels would go up as the developed engines came into service and it was expected that noise reducers on later production models would keep the noise levels comparable with that in the present RA26 powered aircraft.

Did debris from the wheels enter the engine intakes? They had been worried about it, fitted guards or brushes, but found in actual service that there was no more serious problem than with podded jet engines and the risk of trouble due to icing, etc, of the brushes was actually greater.

Asked to comment, Mr. J. T. Dyment stated that the acceptance of any airliner was based on the ability of the aircraft to economically fit the routes of the individual airline. He paid high tribute to the standards of workmanship on the Caravelle and the unusually high standards of cleanliness and materials handling at Sud Aviation's Toulouse plant, which he had visited recently.

Mr. E. H. Higgins thanked General Tessier for his excellent outline and for showing the particularly fine film.

Halifax-Dartmouth

Reported by J. W. Milman

September Meeting

The meeting of the Branch was held in the cinema of the Chief Petty Officers' Mess, HMCS Shearwater, on Wednesday, September 16, 1959. The Branch Vice-Chairman, LCDR G. Cummings, RCN, was in the chair.

The Vice-Chairman gave a short report of the AGM at Keltic Lodge and the monument at Baddeck, for the benefit of those members who were unable to attend. CDR E. B. Morris, RCN, the Branch Councillor, gave a short report on the Council meeting held at Keltic Lodge and outlined the proposed changes to the Bylaws.

Two interesting films from the Maritime Air Command were then shown. The first was called "H-Bomb" and dealt with the Civil Defence aspect and damage caused by an H-Bomb. The second was called "Neptune Mission" and described a typical mission of the Neptune Bomber showing its anti-submarine capabilities.

Winnipeg

Reported by N. J. Thomas

September Meeting

The first Branch meeting of the season was held on the 29th September at the Winnipeg Flying Club.

After an enjoyable dinner, which was attended by 42 members and 16 guests, Mr. B. W. Torrel introduced the new Executive. The Social Committee Chairman, Mr. E. W. Baker, introduced the new members of the Social Committee,

Mr. J. B. Gillings and Mr. W. Ramage, and announced the coming dance to be held in the Marlborough Hotel on the 21st November, 1959.

The Membership Committee Chairman, Mr. S. Sawyer, pointed out that this year's objective of doubling the membership of the Winnipeg Branch would be achieved by each existing member obtaining a new member. Mr. D. C. Marshall, the Programme Committee Chairman, introduced the members of his Committee, Mr. J. F. Sears and Mr. A. Trupp, and outlined some of the possible programmes planned for the season. These included discussions of the Caribou, CL-44 and Argus aircraft and the Rolls-Royce Tyne and Conway powerplants. He also invited members to suggest any other topics they would like to hear.

Mr. J. G. Davidson introduced the guest speaker of the evening, Mr. E. L. Bunnell of Bristol Aero-Industries, who gave a very interesting and informative outline of the design and development of the Lockheed Jetstar aircraft from the preliminary design studies in 1944 to his recent opportunity to fly the finished aircraft as the third person outside the Lockheed personnel to ever do so. Highlights of the Jetstar development noted were: the short time to build the prototype once this decision to build was reached—8 months; the rear pod mounted engines and the many advantages of this engine location; the availability of either a 2 or 4 engine configuration (Bristol supply the Orpheus engines for the twin-engine variant); the ease of handling even on a single engine; the special wing attachments which avoid running a conventional spar through the fuselage and the easy maintenance accessibility.

After a few short films on the Jetstar's first flight, and on some of the test work carried out, W/C C. J. Evans thanked the speaker for the interesting talk, particularly mentioning the nice balance of time and detail given the subject.

10TH DECEMBER, 1959

THE OTTAWA BRANCH

will hold a Luncheon Meeting in the Main Dining Room
of the Chateau Laurier at 12.30 p.m. on the 10th December.

Dr. Herbert F. York

Director of Defense Research and Engineering

U.S. Department of Defense

will be the Guest of Honour and Principal Speaker.

The Luncheon will be attended by senior representatives
of Government Departments, Research Organizations and Professional Societies.

All members of the Institute are invited.

Tickets, price $3.25, are obtainable from

W/C A. N. le Cheminant
Secretary, Ottawa Branch C.A.I.
2300 Fox Crescent
Ottawa

MEMBERS

AGARD: Dr. T. von Kármán, Chairman, with Dr. D. C. MacPhail (l) and Mr. J. L. Orr (r), Canadian delegates to the National Delegates Meeting

R. N. Lindley, F.C.A.I., formerly Chief Design Engineer of Avro Aircraft Company Limited, has taken a position with McDonnell Aircraft Corp., St. Louis, Missouri.

Dr. D. C. MacPhail, F.C.A.I., was appointed Chairman of the Wind Tunnel and Model Testing Panel of AGARD, during the 9th General Assembly, 1959.

G. Hake, A.F.C.A.I., has resigned his position as Quality Control Manager and Chief Inspector at Avro Aircraft Limited and has returned to the United Kingdom after twelve years in Canadian aviation.

W. H. D. Hanchet, A.F.C.A.I., has been appointed Assistant Project Engineer, CL-44 Aircraft, Canadair Limited.

J. R. S. Hutton, A.F.C.A.I., formerly Assistant General Manager of Bristol Aero-Industries Ltd., Vancouver Division, has now been appointed General Manager.

F. C. Phillips, A.F.C.A.I., Canadair Limited, formerly Chief Staff Engineer, Research and Development, has been appointed Assistant Chief Engineer—Technical.

D. C. Weiss, A.F.C.A.I., formerly Project Representative at the University of Michigan, has recently taken a position as a Research Staff Member to General Atomic, San Diego, California.

H. H. Whiteman, A.F.C.A.I., has recently been appointed Chief Project Engineer for Production Aircraft at Canadair Limited.

D. G. Allan, M.C.A.I., has been posted to London, England, as Boeing 707 Field Service Engineer with the British Overseas Airways Corporation.

H. G. Farish, M.C.A.I., has been appointed Senior Engineer—Technical of the Montreal Division of Bristol Aero-Industries Ltd. Prior to that he was Quality Control Manager of the same Division.

R. Mascall, M.C.A.I., has recently taken a position with Canadair Limited, Montreal, as a Liaison Engineer.

T. Roberts, M.C.A.I., has taken a position as Aeronautical Research Engineer, Space Task Group, NASA, Langley Field.

R. B. Shannon, M.C.A.I., formerly with Avro Aircraft, is now with North American Aviation, Columbus, Ohio, as a Senior Design Engineer (Armament).

W. W. Bryce, Technical Member, has joined the staff of North American Aviation Inc., Columbus, Ohio, in their Dynamic Sciences Dept.

AGARD (l to r): Dr. T. von Kármán, Chairman of AGARD, Mr. F. R. Thurston and Mr. D. C. Smith, Chairman and Executive respectively of the Structures and Materials Panel

ANNUAL GENERAL MEETING

The Annual General Meeting of the Institute will be held at

THE CHATEAU LAURIER, OTTAWA

on the

24th and 25th May, 1960

The Programme, which is now being prepared, will include Sessions on

Man in Space
Air Freight (Cargo handling, Freighter design, Northern logistics)
Design and Manufacture (Miniaturization, Small run production, Management)

as well as the annual Business Meetings of the Institute and the Specialist Sections.

This meeting affords an opportunity for the presentation of papers by members of the C.A.I. The Council is most anxious to encourage Canadian papers and hopes that any member wishing to contribute to any of the above-mentioned Sessions will submit a summary of his paper for consideration. Such summaries must be in the hands of the Secretary by the 31st December, 1959.

SUSTAINING MEMBERS

Salvage of a Norseman

NEWS

Field Aviation Company Limited have announced that a crashed aircraft has been economically recovered from the Quebec wilderness in a salvage operation carried out near Hudson Strait, more than 1,000 miles north of Montreal.

The aircraft – a Norseman employed by a mining exploration company at the northern tip of the Ungava area – flipped over while attempting a takeoff from Otter Lake and landed on its back on a sand bar. The tailplane, one float and propeller were smashed beyond repair and the cabin damaged. But the fuselage, wing and engine were intact.

When replacement parts arrived, the salvage operation was rushed to completion and the Norseman was test flown. Then, after the Department of Transport had radioed permission, the salvaged aircraft was flown out in easy stages to Oshawa, where overhaul and winter refitting will be carried out.

The entire job, which required only about four days of actual work, covered a three-week time span. Transportation of men and materials to the site and the vagaries of northern weather (winds up to 80 mph, rain and fog allowed only two favourable working days a week) were responsible for the delay.

Nevertheless the operation was successful, financially as well as technically. Although salvage and repair costs – estimated at $17,000 over-all – were roughly double those incurred in readily accessible areas, the recovery of a $30,000 aircraft more than justified the expenditure.

Bristol Aero-Industries Limited have announced that four more Britannia airliners have been ordered, two by Transcontinental of Argentina, South America, and an additional two by Canadian Pacific Air Lines, Limited. The CPAL order brings the Britannia fleet to a total of eight aircraft. Transcontinental will operate the Britannias on its international route between Buenos Aires and New York. Deliveries of all four aircraft will be made by the end of November this year.

The De Havilland Aircraft of Canada Limited have delivered the first YAC-1 Caribou STOL transport aircraft to the United States Army. By the end of November, 1959, four more aircraft will be delivered, completing an order for five for evaluation purposes by the US Army.

The Caribou, a 26,000 lb transport, is designed to operate from short unprepared fields or hastily improvised battle area landing strips with an official specified takeoff and landing distance of 540 ft and 525 ft respectively.

The airplane is the first in its weight category in the world designed primarily for short field takeoff and landing. The original concept was a utility aircraft designed to initiate regular daily

The De Havilland Caribou

scheduled air services into the undeveloped areas of the world where airports are practically unknown and maintenance facilities are few and far between. Like the jetliner pioneers in the field of high speed transport aircraft development, De Havilland of Canada engineers encountered some unusual problems in the hitherto unexplored realm of control and maneuverability of such a large aircraft as the Caribou at low speeds. Three years of intensive design studies, prototype construction and experimental development went into the Caribou before the type certificate was granted in August, 1959, by the Department of Transport.

De Havilland's original thinking on the Caribou was based on the idea of a "twin-engine Otter", designed around the Otter's two 600 bhp engines, having a fixed landing gear and a gross weight of around 13,000 lb. This concept failed while it was still on paper because when CAR-4B requirements had to be realized it was found that the twin-engine Otter could not carry a payload appreciably larger than that of its single engine counterpart. The necessity for substantially larger payloads pushed the weight up to 22,000 lb and the powerplants to 1,200 bhp. Subsequent design studies increased the weight to 24,000 and finally to 26,000 lb. Power requirements increased from the original 600 bhp to 1200 bhp and eventually finalized in the selection of two 1,450 bhp Pratt & Whitney R-2000's. These were considered to be minimum requirements for a twin-engine transport airplane that could meet CAR-4B requirements for single-engine operation and still achieve better than average operating economy.

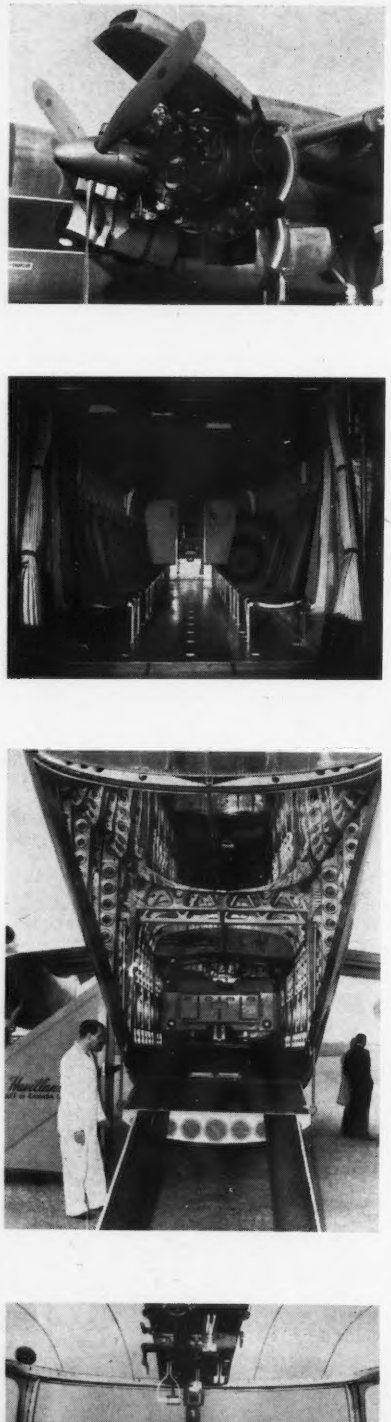
Basically, the DHC-4 Caribou is an all weather utility transport aircraft. Primary purpose of the airplane is to serve as a commercial vehicle designed to offer low-cost transportation of passengers or cargo, or combinations of both, over the world's air routes, particularly in undeveloped areas. In the design and development of the aircraft, the requirements of the feeder airline operator have been kept constantly in mind. During the early formative stages of development, however, it was apparent that a STOL transport airplane of this type would prove ideally suitable as a close support plane for armies in the field. Ideas were exchanged with military experts both at home and abroad. In the end, military requirements exerted a considerable influence on the final configuration of the Caribou. The final decision to go ahead with the production was triggered by an offer from the Canadian Army to contribute 2½ million dollars towards the development. The order for five aircraft for evaluation placed by the United States Army in March 1957 was an "off the shelf" order. Military thinking, nevertheless, played a large part in the production of an aircraft that is tailor-made to the new rapid mobility requirements of armies in the field.

In its military version, the Caribou cannot accurately be described as either "tactical" or "strategic". It is an *organic* vehicle – a three ton flying truck whose mission is the rapid airlift of men and supplies. Its function is exactly that of the truck convoys in wars of the past but geared to the lightning speed that the new concept of war will demand of army transportation in any war of the future. In the movement of men and supplies to the battle front, the Caribou forms an important link in the chain. First will come the long haul by heavy long-range transports of Air Force Transport Command. These planes will ferry their loads to the most usable super airport located within reasonable distance from the combat zone. The loads will there be transferred to Army YAC-1 Caribous for delivery to advanced dirt landing strips available close-in to the battle area. Here they will be transferred to helicopters for their final hop and VTOL delivery to front line battle positions.

In the matter of Army logistic support the Caribou should prove invaluable.

STOL performance, combined with versatility of utilization, was the prime objective of the Caribou design team. This has been achieved. Its payload capacity of up to three tons will accommodate substantially bulky cargo in its 1,150 cu ft cabin. Cabin access for rapid loading and unloading is provided by the 73.5" × 75" rear loading door. The military version will seat up to 32 combat troops or, as an ambulance, a variation from fourteen litters to combinations of litter, sit-up patients and medical attendants. Two jeeps can be rapidly delivered by Caribou. These can be driven into the cabin under their own power. The cabin deck is of honeycomb construction and designed at the same floor level as a 2½ ton truck for convenient loading and unloading of heavy cargo. The civil version of this airplane will carry up to thirty passengers, each with thirty pounds of luggage.

Beneath the deck, the structure features an exceptionally strong keel consisting of three longitudinal beams with continuous flanges supported at short intervals by traverse frames. The honeycomb floor will carry a distributed load of 200 psf and has a reasonable capacity for point loads.



Features of the Caribou, showing its simplicity and versatility

The upsweep of the rear fuselage contributes to the ease of loading and unloading and thereby facilitates a reduction in turn-around time. The clearance under the tail is 9½ ft, allowing a truck to back up into the rear loading door opening, affording quick loading into the cabin.

The cockpit features airline duplication of instruments enclosed in an "office" consisting of 32 sq ft of glass. This expanse of glass provides unobstructed all-round vision in flight and on the ground in a 265° forward range. A sliding radio console between the pilots can be stowed completely under the instrument panel when not in use. An overhead engine-control quadrant adds further to the crew's freedom of movement.

Short over-obstacle landings on rough, unprepared strips is commonplace performance for the military and civil operated Beavers and Otters throughout the world. This "commonplace" is an essential feature of airplanes employed on battle zone and remote area transport missions and was pioneered by De Havilland Aircraft of Canada. Both airplanes, the 5,100 lb (all up weights) Beaver and the 8,000 lb Otter feature rugged fixed undercarriages designed to meet this requirement. When the Caribou at 26,000 lb went onto the drawing board the incorporation of this "commonplace" into its performance posed many problems. One being the development of an undercarriage structure that

Loading the Caribou

would be relatively light and simple, yet rugged, with a high energy capacity.

A tricycle undercarriage with relatively large dual wheels was decided upon after considerable investigation. Of conventional appearance, this gear incorporates several unique features, one of these being the two-stroke shock strut. This component combines the long-stroke leg function necessary for short-field, over obstacle landings and the short-stroke leg platform stability that minimizes spongy performance while taxiing over rough terrain or during loading operations.

An interesting feature of the main legs is the mechanism which shortens the gear by some 18 inches to permit it to stow in the nacelle. The shock strut is not compressed in this process, but slides as a complete unit inside the main structure of the gear. Either one of two engine-driven hydraulic pumps can retract the gear in 6 seconds. The ability to "clean up" quickly on takeoff provides a good dividend in climb performance.

In addition to the engine-driven pumps, a hand pump is available in an emergency. As a further safeguard a mechanized release is provided which will drop the main gear under gravity and a compressed air bottle is available for the purpose of blowing down the nose gear.

The gear is forward retracting, thus, in the event that a gravity drop is necessary, the pressure from the slip stream aids the operation.

Powered by two Pratt & Whitney R-2000 7M2 (1450 bhp at takeoff) engines, the DHC-4 Caribou is of conventional high wing cantilever design, featuring fullspan, double slotted flaps and a generous wing area. This configuration provides excellent control and maneuverability for the low level, low speed operations peculiar to air vehicle utilization for battle zone and remote area transportation.

The Caribou made its debut in September 1958. Since that date the airplane's gross weight has been increased by 2,000 lb (from 24,000 lb to 26,000 lb) with a 45 inch lengthening of the fuselage. This modification, while adding to the airplane's useful load capacity, has not immediately affected its performance.

APPOINTMENT NOTICES

The facilities of the Journal are offered free of charge to individual members of the Institute seeking new positions and to Sustaining Member companies wishing to give notice of positions vacant. Notices will be published for two consecutive months and will thereafter be discontinued, unless their reinstatement is specifically requested. A Box No., to which enquiries may be addressed (c/o The Secretary), will be assigned to each notice submitted by an individual.

The Institute reserves the right to decline any notice considered unsuitable for this service or temporarily to withhold publication if circumstances so demand.

Positions required

Box 109 **Engineer:** Canadian Citizen with Cambridge University Master's Degree and 20 years continuous experience in aeronautical engineering, seeks a new responsible position preferably in the Toronto area. Experience includes: RAF Engineer Officer, technical sales, technical administration, research, aerodynamics, thermodynamics, electronics, meteorology and instrument design and development. AFRAeS in 1947; AFCAI in 1954.

Box 110 **RCAF Aeronautical Engineering Officer** shortly leaving the service on completion of a short service commission seeks position in the aircraft industry in Canada. Educated in England to Higher National Certificate standard, his background includes six years at the Royal Aircraft Establishment, Farnborough, as a student apprentice followed by a term as Assistant Experimental Officer engaged in research and development on reinforced plastic structures. His present position involves close liaison with industry in the repair and overhaul fields. Member grade in the CAI is held. A full personal history will be sent on request.

Position vacant

Technical Author (Electrical): Required by an aircraft plant in Edmonton, Alberta. Applicants must have had at least three years experience in Aircraft Publications work. Good salary plus relocation expenses to an approved case. Medical and hospitalization benefits plus pension plan, after a qualifying period. Write giving full particulars of age, education, qualifications and salary required to: Industrial Relations Manager, Northwest Industries Limited, Box 517, Municipal Airport, Edmonton, Alta.

BOOKS

An Introduction to the Dynamics of Framed Structures. By G. L. Rogers, John Wiley & Sons, New York, 1959. 350 pages. Illus. $10.25.

The author has set out with the self-expressed intention of writing an introductory work on the dynamic analysis of structures, with the special problems of bridge and building designers in mind, partly necessitated by other such writers whose "orientation was much more toward the design of machines and aircraft than was satisfactory for structural engineers". Aeronautical engineers will not deny that designers of space frames are faced with difficult problems of numerical analysis, with simultaneous equations running into a very high order particularly in the general case of a bridge framework or multi-storey building. Superimposed on a basically messy problem one must now cater for the forces of an atomic blast on the one hand, and a growing emphasis towards structural efficiency on the other. Here is a real stamping ground for applied engineers and theoreticians alike. What would form a good introduction to the special problems of this subject? Dr. Rogers has replied with the "Dynamics of Framed Structures".

The book is not without merit and not without fault. Meritworthy is an emphasis on the structure of forcing functions and the blast pressure process, and an earthy application of moment-balancing procedures of plane frame static analysis to the calculation of dynamic elastic parameters. The author is to be criticized for a badly organized treatment, which races into the analysis of frames before he has established a real feeling for their dynamic characteristics. This is his deliberate preference to the classical introduction. Granting him this license, it is still disconcerting to find a simple bent as an example of a structure with one degree of freedom, even with a rigid girder.

In spite of a fast start, Dr. Rogers limits himself to plane frames forced in their plane and, after treating the limited modes of shear buildings, is obliged to revert to a more orthodox treatment of beams, single and continuous. Here he hits a fine stride, developing a better understanding of dynamic modes, which carries him briefly into the field of plane bents with elastic columns and girders, and elastic floor systems. There is no discussion of trusses, and no discussion of aeroelastic type instabilities.

A. H. Hall

Materials for Rockets and Missiles. By R. G. Frank and W. F. Zimmerman, Brett-Macmillan Ltd., Galt, Ont., 1959. 124 pages. Illus. $4.50.

This is a very concise book, in which the authors attempt to bring together sufficient data on the elevated temperature properties of existing high temperature alloys, aluminum and magnesium alloys, titanium alloys, cermets, ceramics and molybdenum alloys to enable the design engineer to evaluate these materials for elevated temperature service of the type encountered in rocket engines, nose cones and other rocket and missile components that must operate at elevated temperatures. It is not intended to supply data that can be used directly for component design. Trends in the development of new materials for very high temperature applications are also discussed and a chapter on new methods of material fabrication is included.

A basic set of mechanical properties is presented graphically for all the materials discussed over the temperature range for which data is available. These properties are tensile strength, 0.2% yield strength, tensile elongation, 10 hour and 100 hour stress rupture properties and fatigue strength for 10^8 cycles. The density, modulus of elasticity, coefficient of expansion, thermal conductivity, impact strength (where available) and nominal chemical analysis are presented in tabular form.

There is some discussion of such matters as oxidation resistance, maximum service temperature, formability, weldability and brazing and strengthening mechanism of specific alloys within a group in an attempt to provide some basis for the selection of alloys for specific types of applications. The special service conditions and environments encountered in missile and rocket applications are discussed, particularly in their relationship to service conditions and environments encountered in jet engines.

All of this discussion has been so written that one does not need to be a specialist in physical metallurgy or solid state physics to follow it readily. A selected bibliography is included so that those who wish to obtain more detailed information on any specific item may do so.

In the reviewer's opinion this is an excellent book for the executive who doesn't wish to be burdened with detail but must keep abreast of developments in the field of high temperature materials and for the design engineer who wishes a quick review of the materials available for high temperature applications.

H. V. Kinsey

Applied Hydrodynamics. By H. R. Vallentine, Butterworth & Co., Toronto, 1959. 272 pages. Illus. $10.00.

This book provides an unusually interesting combination of the mathematical and engineering approaches to fluid dynamics. While the list of contents correctly suggests an emphasis towards the classical hydrodynamics of Lamb, many more practical illustrations are presented than is common in the standard, more rigorous works; and clear physical explanations precede the mathematical treatment of every topic. Moreover, the interjection of a chapter on viscosity and general boundary layer phenomena, immediately following the introductory chapter on ideal fluid-flow, materially helps the beginner to appreciate both the limitations and the power of classical hydrodynamics.

Quoting the author, the book is intended for use in universities as an introduction to hydrodynamics for students of applied mathematics, and as a course in fluid dynamics for senior and post-graduate students in civil, mechanical and aeronautical engineering. In the reviewer's opinion, the general manner of presentation should appeal particularly to the practical aeronautical engineer or naval architect who feels the need to back his knowledge with the classical fundamentals, which, in recent years, have been so rapidly assuming increased practical importance.

A notable feature, in a short book starting from first principles, is the inclusion of two long chapters on conformal transformation and an introduction to free streamline theory, Also unusual are the useful explanations of simple methods of graphical and numerical analysis. Both of these topics reflect the practical bias and modern approach of the book.

The diagrams, a most important part of a work of this type, have been exceptionally well prepared, but in a few instances the overall effect has been spoiled by unnecessary reduction in size and cramped presentation. There are a few minor printing errors.

M. C. Eames

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